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ANNUAL PROGRESS REPORT

FISCAL YEAR 1979

(1 October 1978 - 30 September 1979)

U S ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

Natick, Massachusetts

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UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

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Biophysics	Climatic Exposure	Cryobiology

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A report of progress on the research program of the US A of Environmental Medicine for Fiscal Year 1979 is presen

Program No.	Project No.	Task No.	Title
6.11.01.A	3A161101A91C	00	In-House Laboratory
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			Medical Factors in

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Dehydration
Disabilities
Endo-helial Cells
Endotoxin
Energy Expenditure
Environmental Medicine
Environmental Stress
Environmental Tolerance
Evaporative Cooling Index
Exercise At High Altitude
Fasciotomy
Fitness
Frostbite
Health Risk Factors
Heat
Heat Disabilities
Heat Stress
Heatstroke
Hepatic Necrosis
Human Performance at Altitude
Human Performance in Cold
Human Performance in Heat
Hyperthermia
Hypothermia
Hypovolemia
Insulation (clo)
Isolated, Perfused Rat Liver
Mental Fatigue
Military Disabilities
Military Heat Stress
Military Operations
Military Tactics
Motivation
Muscle Strength
Obesity
Osteocytes
Pathology Model
Performance Limits
Peripheral Blood Flow
Physiology
Protection
Psychomotor Functions
Questionnaires/Interviews
Reticuloendothelial
Spontaneous Motor Activity
Survey Analysis
Sustained Human Performance
Sustained Operations
Symptoms Self-Reports
Team Performance
Terrain Coefficients
Thermal Exchange
Thermography
Thermoregulation
Thyroid Function
Tissue Culture
Tolerance
Tolerance Prediction
Ultrastructure
Vasodilation
Ventilatory Acclimatization
Ventilatory Muscle Training
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US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE

NATICK, MASSACHUSETTS

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ANNUAL PROGRESS REPORT

FISCAL YEAR 1979

(1 October 1978 - 30 September 1979)

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UNITED STATES ARMY
MEDICAL RESEARCH & DEVELOPMENT COMMAND

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3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	D. Change	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.01.A	3A161101A91C	00	020
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)* (U) Development of Survey Methodology for Analysis of Environmental Medical Illness and Risk (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 007900 Occupational Medicine; 012500 Personnel Selection, Training; 005900 Environmental Biology; 013400 Psychological; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
78 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

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18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
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19. RESPONSIBLE DOD ORGANIZATION

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TELEPHONE: 955-2811

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ASSOCIATE INVESTIGATORS

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NAME: 955-2822 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Survey Analysis; (U)Symptoms Self-Reports; (U)Questionnaires/Interviews; (U)Climatic Exposure; (U)Health Risk Factors; (U)Rating Scales

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Current medical records do not adequately define the number and type of Army personnel who suffer environmentally-induced illness and injury. Data are usually lacking on the population at risk, on treatment follow-up, on partially disabling symptoms which go unreported, on the nature of exposure, and on medical risk factors due to job assignment, individual background, physical condition, and related health behaviors. Such data are needed to direct research, prophylaxis, training, and operational planning.

24. (U) This work unit develops and pilot tests new methods for survey sampling and epidemiologic studies of Army personnel exposed to specific climatic extremes and physical demands in training exercises. Questionnaires, structured interviews, personnel and medical record survey forms and observation procedures for the collection of subjective and objective data regarding exposure, symptoms, incapacitation, illness and injury under specific conditions are designed, sample tested, revised and validated for subsequent routine use in other work units.

25. (U) 78 10 - 79 09 Prototypes of an Environmental Background Survey Questionnaire and Environmental Symptom Questionnaire were administered to 96 mechanized infantryman before and after air deployment from Texas to Europe; the results were analyzed and included in the final report of the USAMRDC-mandated study of Jet Lag. The questionnaires were refined by factor analysis and have undergone further testing in a laboratory study. A Current Assessment Inventory (to record subjects' account of exposure to conditions) and a Survival Quiz for Extreme Climates (to assess subjects' knowledge of hazards and correct preventive measures) are ready for initial pilot testing. Further development of the questionnaires described above will continue under a new work unit within the Basic Sciences program. In FY '80, this ILIR work unit will be used to evaluate behavioral observation and scoring procedures and to develop audiovisual aids for briefing large subject audiences on how to complete the questionnaires.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	020 Development of Survey Methodology for Analysis of Environmental Medical Illness and Risk
Study Title:	Development of Survey Methodology for Analysis of Environmental Medical Illness and Risk
Investigator:	James B. Sampson, Ph.D.

Background:

USARIEM has mission responsibility for research into the medical problems associated with operations in hot, cold, and high altitude climates and also with physical fitness training programs. One approach is to use epidemiological and survey methodologies to document the nature and circumstances of environmentally-induced symptoms, illness and injury actually suffered by troops during training, field exercises and deployments. However, the current medical reporting system retains for automated retrieval only those cases who are admitted for treatment as inpatients longer than 24 h, thus not revealing many disabilities that have operational significance. Observations by USARIEM observers during desert and cold weather exercises (1,2) indicate that even these limited medical records are unreliable and potentially misleading. Unit after-action reports (when obtainable) rarely supply the details on unit composition, prior training or experience, activities and environmental exposure that would be needed to describe the population at risk and support epidemiological inferences about etiology. Quantitative data on environmentally-casuses illness, injury and ineffectiveness (obtained from and expressed in terms of actual Army populations) are needed to guide medical research on prevention and treatment, training doctrine, and operational planning for combat. Such data could also stimulate major savings by reducing disability, death and lost work-hours during peacetime training. Finally, the techniques and experience developed would be the nucleus for data acquisition regarding potentially serious problems in the event of actual mobilization and deployment to harsh climates.

The same methodologies which would improve USARIEM's capability in large scale field epidemiological and survey research would also be evaluable in

small scale laboratory or field experiments. Standardized self-report symptom questionnaires can provide perspective for interpreting physiological or objective performance data, not only within a single study but also in comparisons across studies and with findings from the field. Background information obtained from the small number of test subjects used in experiments can be compared with normative data from Army populations to determine how widely the findings can be generalized.

This ILIR work unit was established to begin initial development of survey instruments (e.g. questionnaires, structured interview formats, behavioral observation techniques and record survey procedures) for use in specific Army contexts. Compactness, ease of administration and scoring, and acceptability to Army test subjects, as well as content, were important considerations.

Progress:

Development proceeded on several questionnaires:

The Environmental Symptom Questionnaire (ESQ) is a question general purpose survey instrument which elicits self-reports of a broad spectrum of somatic and psychological symptoms, designed for use in any environmental conditions. Originally adapted from the General High Altitude Questionnaire (GHAQ), the ESQ had already undergone revision (3) and in fall 1978 was administered to subjects in the "Jet Lag Study" of troops deploying by air from Texas to Germany (4), described elsewhere in this annual report under WU 009. The ESQ was also administered in the study of heat acclimatization of males and females reported under WU 005; data analysis is in progress. Factor analysis of the ESQ is reported under WU 015, a work unit in the Defense Research Sciences program which was created in May 1979 to continue operational testing and final development of instruments developed under this ILIR WU 020.

The Environmental Background Survey (EBS) was designed to obtain information on age, sex, marital status, education, place or origin and other demographic data. The questionnaire also asks about experience and attitudes towards climatic extremes and adverse weather, health habits and current health status. Many of these factors have been related to incidence of cold injury and may also contribute to heat intolerance. The EBS was also administered during the Jet Lag Study and is undergoing further refinement.

The Current Assessment Inventory (CAS) was prepared to obtain reports from subjects or identified patients of their recent exposure to environmental factors, working conditions and task load. Revisions were made to simplify completion of the questionnaire and subsequent scoring.

The Cold Weather Survival Quiz was written in two versions for administration to troops to evaluate their knowledge of cold weather risks and protective measures. Possible uses include testing troops with the questionnaire a) before briefings, lectures, or actual field exercises to assess areas of ignorance or to identify individuals requiring special teaching, and b) again after briefings or field exercises to assess learning. The questionnaire could also be used by troops for self-evaluation and as a teaching tool. Similar questionnaires are planned for hot wet, hot dry and high altitude conditions.

Questionnaires provide one source of survey data; another potentially more flexible means is the structured interview. Large scale use of this method would require training supporting personnel, many of whom are not behavioral scientists, in a standard procedure. Accordingly, a videotape briefing and an outline course of instruction were prepared.

On site measurement of physical conditions encountered by test subjects may also be required in future field studies. In addition to those meteorologic parameters already studied at USARIEM (temperature, humidity, wind speed, radiant heat and barometric pressure), other atmospheric phenomena have been reported to influence health and performance. A literature search was therefore conducted in the field of Biometeorology. An extensive, if somewhat controversial literature was found linking a net excess of small positively charged air ions with upper respiratory and migraine-like symptoms, malaise, behavioral and mood disorders, decreased productivity, and increased accidents. These syndromes occur naturally in association with or in advance of: a) hot dry winds off deserts (e.g. the Sharav of the Middle East, the Santa Ana of the southwest United States) and b) certain winds off mountain ranges (e.g. the Chinook of the US Great Plains, the Foehn of Bavaria). Differences in air ionization, perhaps in conjunction with low humidity as well as hypoxia, have been suggested to explain the marked differences in Acute Mountain Sickness observed in different localities at the same altitude. As these problems clearly fall within USARIEM's mission responsibility, a new ILIR work unit (WU 025) will be started to develop the capability of the Institute to measure subtle biometeorologic variables and to

conduct initial laboratory studies to investigate the effects of air ions under varying conditions of temperature, humidity and barometric pressure.

ILIR WU 020 will continue in use to develop prototype survey instruments. Existing questionnaires will be adapted to use the optical scanning system at NARADCOM for rapid scoring and data analysis. Videotaped briefings will be prepared to familiarize trops with how to fill in specific questionnaires; after testing and revision, these briefings may be reproduced on film for showing to large subject audiences. Evaluation will be made of commercially available hand-held event recorders which store observational data (event codes and time of occurrence) for subsequent entry into computors for analysis; these may be tested in field and laboratory applications.

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2. McCarroll, J. E., R. E. Jackson, C. A. Traver, R. C. Langevin, P. W. Phair, C. A. Murray and L. J. Farese. Morbidity Associated with Cold Weather Training. Military Medicine. 144(10)680:684, October 1979.

3. Kobrick, J. L. and J. B. Sampson. A new inventory for the assessment of symptom occurrence and severity at high altitude. Aviat. Space Environ. Med. 50(9)925:929, 1979.

4. Report No. T 3/79 Effect of Transatlantic Troop Deployment on Physical Work Capacity and Work Performance. US Army Research Institute of Environmental Medicine, Natick, MA March 1979.

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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
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79 04 30	H. Terminated	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.01.A	3A161101A91C	00	021
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)

(U)The Effects of Heat on the Structure and Function of Perfused Rat Liver (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS

005900 Environmental Biology; 002300 Biochemistry; 012900 Physiology; 010100 Microbiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 04	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER: NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
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19. RESPONSIBLE DOD ORGANIZATION

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NAME: HAMLET, Murray P., D.V.M. DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Heatstroke; (U)Hepatic Necrosis; (U)Isolated, Perfused Rat Liver; (U)Hyperthermia

23. TECHNICAL OBJECTIVE. 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The objective of this research is to determine at what temperatures metabolic, histological, and ultrastructural changes occur in the isolated perfused rat liver due to heat exposure. These parameters will then be used to evaluate the role of the liver in heatstroke independent of the complex mechanisms operating in the whole animal. The effects of a variety of heat generated substances can also be ascertained. An understanding of the mechanisms of heat-induced lesions may lead to the formulation of therapeutic agents specifically designed to negate these factors.

24. (U) Pathological changes in the liver are among the most consistent findings subsequent to heatstroke. A systematic study of heat-induced injury to the isolated perfused organ should yield valuable insight into the mechanisms of tissue damage independent of the complexities encountered with whole animals. By perfusing fluids at known temperatures, the critical temperatures for endothelial and parenchymal cell injury can be established using light and electron microscopy, potassium release, dye clearance, release of GPT, glucose metabolism and oxygen consumption. The effects of perfusate containing precise amounts of chemically pure substances thought to play a role in heatstroke or containing cellular fluids from heated animals can be ascertained.

25. (U) 78 10 - 79 09 We have detected evidence of irreversible hepatocellular necrosis at 41, 42 and 43°C, with a 90 minute exposure, but not at 37, 39 and 40°C. When groups of isolated livers were perfused at 43°C for different time intervals GPT and GOT release and bile production were normal for 30 min. After 45 min. these parameters indicated damage which became more severe at 60 and 75 min. Ultrastructure indicated occassional necrosis of individual cells after 15 min. and focal cellular necrosis after 30 min. along with significant reduction in the amount of glycogen. Since no flocculent dense bodies were detected in mitochondria after 30 min. exposure, the damage at this point may be reversible. Ultrastructure was the most sensitive indicator of damage. This work will be continued under another work unit (010).

DD FORM 1498, 1 MAR 68 — PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Project Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	021 The Effects of Heat on the Structure and Function of the Perfused Rat Liver
Study Title:	The Effects of Heat on the Structure and Function of the Perfused Rat Liver
Investigators:	Wilbert D. Bowers, Jr., Ph.D., Roger W. Hubbard, Ph.D., Murray P. Hamlet, D.V.M. and John T. Maher, Ph.D.

Background:

Growing interest in hyperthermia and heat related disorders has been stimulated by the potential for conflict in hot climates, and the use of hyperthermia in cancer therapy (1,2,3). Hepatic necrosis is among the consistent consequences of heatstroke in both humans and animals (4,5,6,7,8). Work in this laboratory demonstrated hepatic lesions in isolated rat livers, perfused under precisely controlled conditions, which are similar to those observed in intact animals and humans after heatstroke. The effects of 90 min exposure at temperatures from 37° to 43°C, in terms of bile production, enzyme leakage, and light microscopy, have been described. This report describes the electron microscopic studies for temperature groups (37° to 43°) of the previous research and the characterization of the relationship between time of exposure (0 to 90 min) and appearance of light microscopic indications of damage.

Progress:

Ninety minutes exposure to temperatures from 41° to 43° resulted in ultrastructural indications of damage (Fig. 1,2,3) which were consistent with earlier light microscopic findings, enzyme release and inhibition of bile production. These tissues were characterized by a loss of sinusidal endothelium, loss of hepatocellular microcilli, depletion of glycogen, fragmentation of cells, vacuolization, and mitochondrial degeneration. The presence of flocculent densities in mitochondria throughout the tissues indicates irreversible damage according to Laiho and Trump (9) and Hagler et al, (10). Figure 4 illustrates the difference

between normal electron dense bodies (circle) and flocculent densities (arrow) in a heated cell.

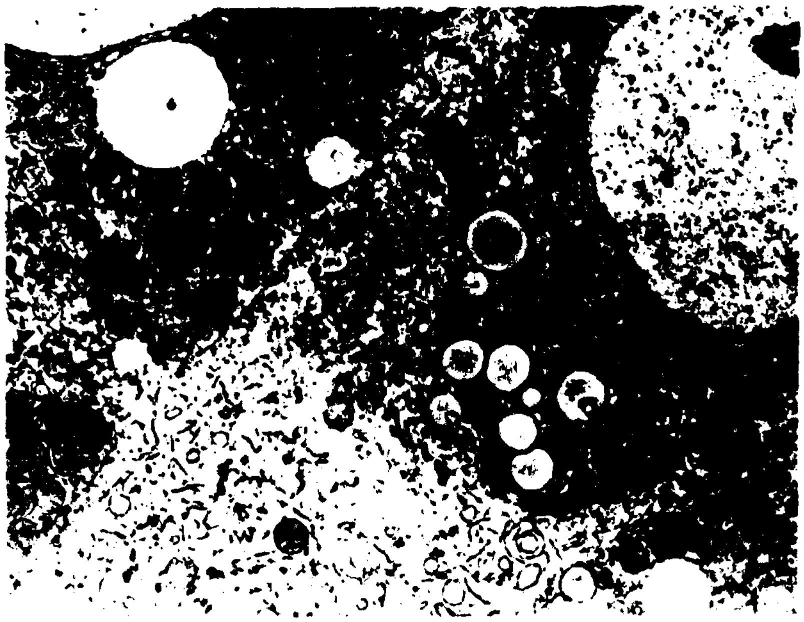

Figure 1. Electron micrograph of rat liver perfused at 41°C

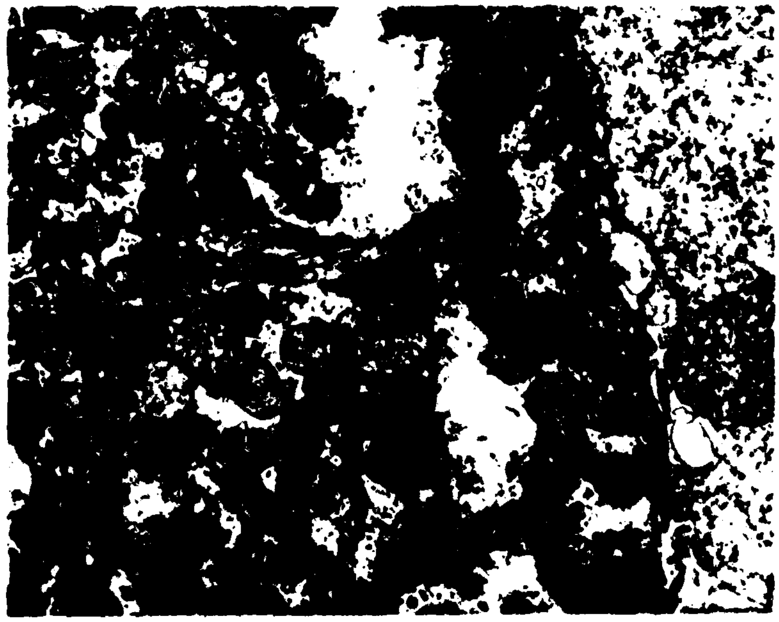

Figure 2. Electron micrograph of rat liver perfused at 42°C

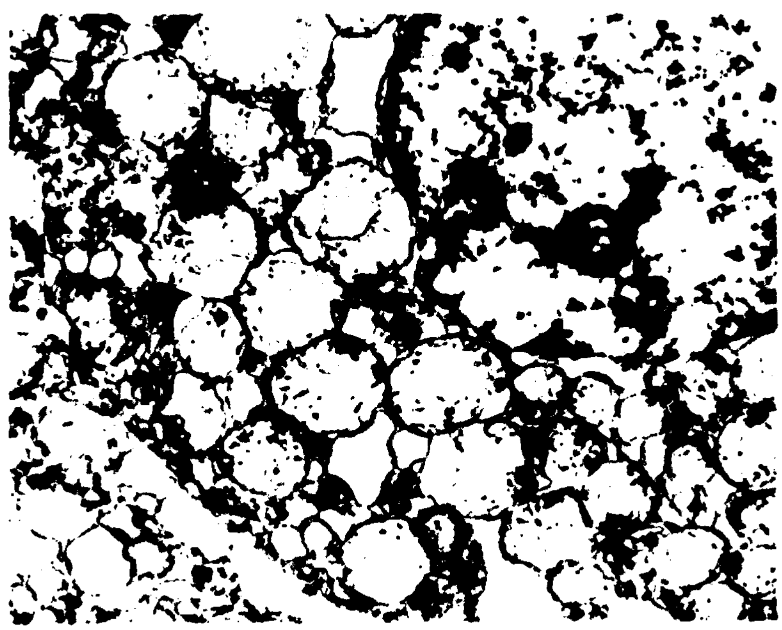

Figure 3. Electron micrograph of rat liver perfused at 43°C

Figure 4. Mitochondria of rat liver perfused at 43°C. Both electron dense bodies (circle) and flocculent densities (arrow) are illustrated.

After exposure for 90 min at 39° (Fig. 5) and 40° (Fig. 6), practically all of the tissues appeared normal; however, occasional individual hepatocellular damage was evident (Fig. 7 and Fig. 8). This is consistent with data of Collins et al. (11) who observed inhibition of protein synthesis at 39°, RNA synthesis at 41° and DNA synthesis at 42°C. Flocculent densities were observed in mitochondria of some of these damaged cells. Such structures were not observed in controls (Fig. 9). Electron microscopy appeared to be the most sensitive indicator of injury, but the focal nature of cellular changes at the lower temperatures necessitates use of multiple parameters. Enzyme leakage, described in a previous report, correlated well with structural damage.

Figure 5. Electron micrograph of rat liver perfused at 39°C

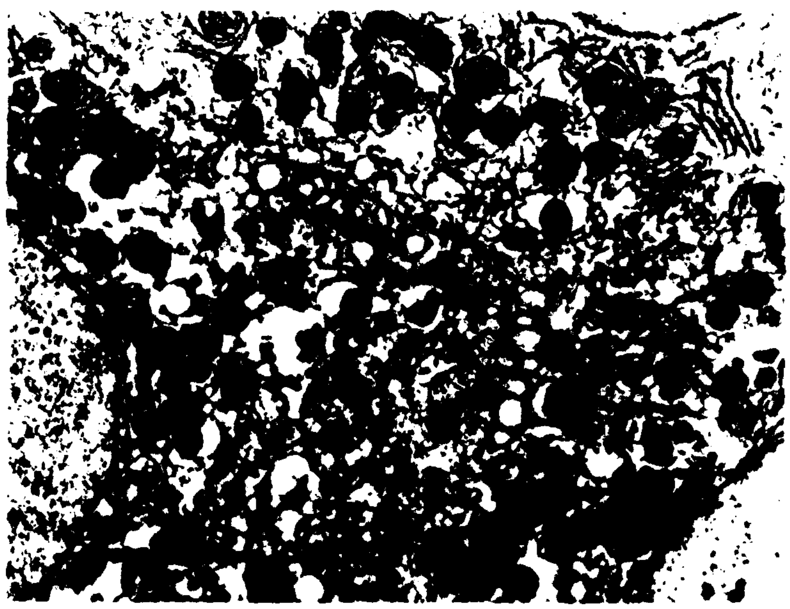

Figure 6. Electron micrograph of rat liver perfused at 40°C

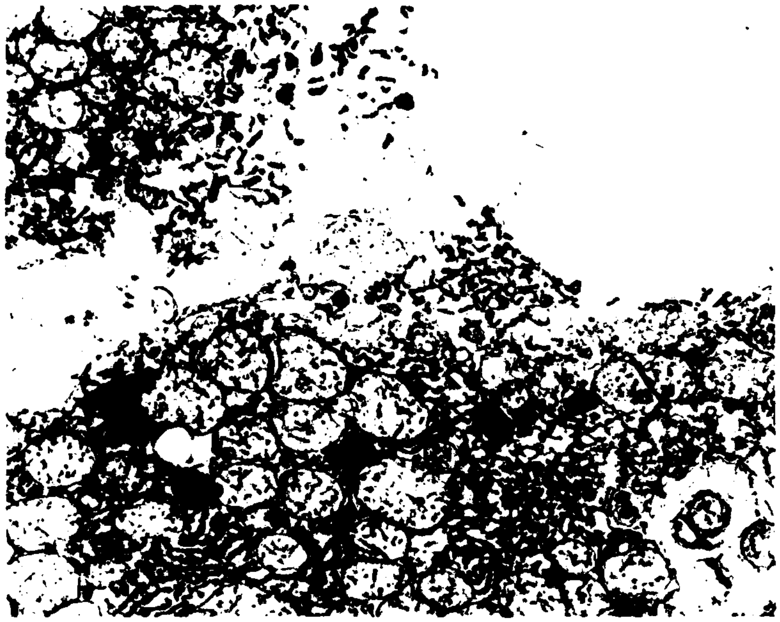

Figure 7. Area of focal hepatocellular necrosis at 39°C

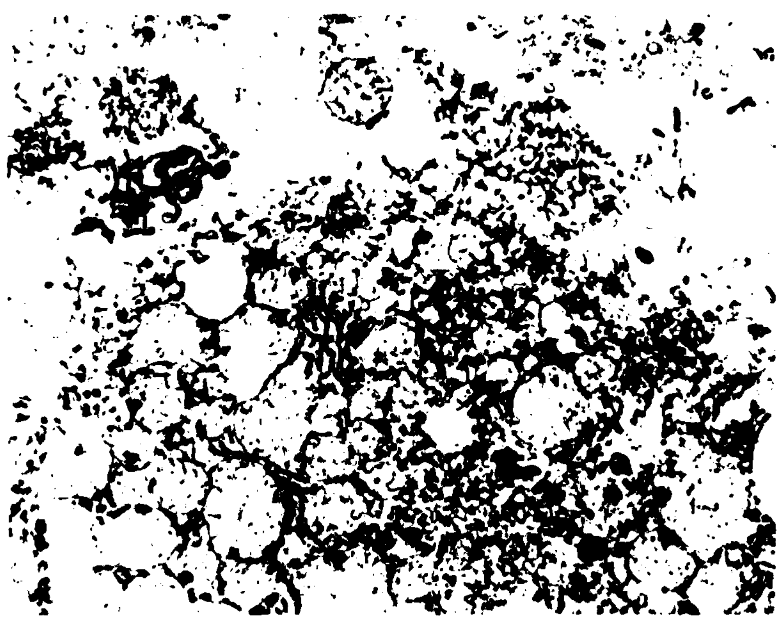

Figure 8. Area of focal hepatocellular necrosis at 40°C

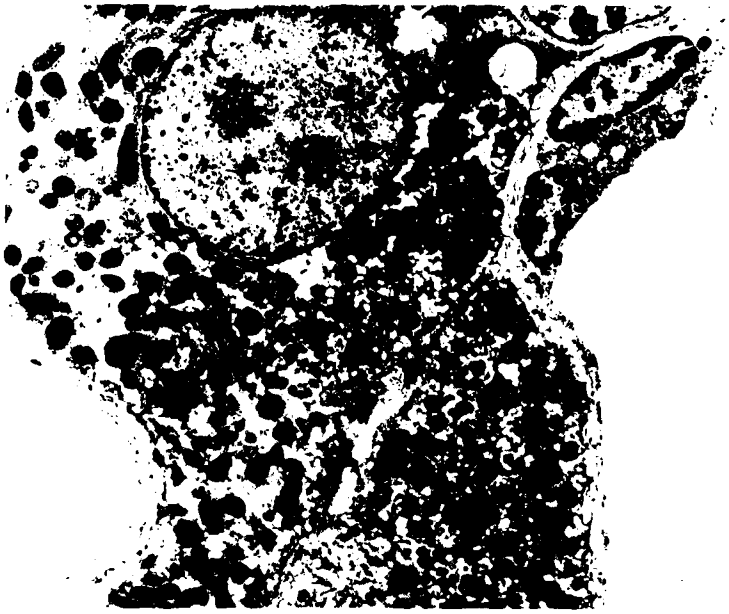

Figure 9. Electron micrograph of control rat liver perfused at 37°C

Hubbard et al. (12) applied the concept which calculates the area of the heating curve (core temperature) above 40.4 in degree-minutes to predict survival rates for rats. In that work, sedentary heating which resulted in an "end of heating" core temperature of 42.2°C produced a total time above 40.4° of 55 $\pm$ 22 min, 44.5 $\pm$ 3.6 degree minutes, and 50-75% mortality. Relating this to the isolated perfused livers, 41°C heat exposure for 90 min produces 54 degree-minutes. In theory, this heat load should produce a mortality rate above 70% in whole rats. On the other hand, exposure to 40°C core temperature for an extended period should not be fatal to either the intact rat or the perfused liver. Our data, in fact, indicate that exposure to 41°-43°C for ninety minutes results in hepatocellular necrosis which is probably irreversible, while at 39° and 40°, the few individual cells which were damaged could probably be replaced.

Since it has been demonstrated by others in both humans (13) and rats (8) that elevations in levels of SGPT and SGOT above 1,000 IU/L, in circulating blood, correlates with poor prognosis for heatstroke victims, it is not unreasonable to assume that a compromized liver would contribute to the adverse effects of heatstroke. Heat alone, even without the other destructive events accompanying heatstroke, can produce severe hepatic damage to perfused rat livers at temperatures as low as 41°C (105.8°F).

All of our previous experiments were run for 90 min at specified temperatures from 37° to 43°C. It was therefore impossible to determine at what time during the 90 min exposure that structural and ultrastructural changes occurred and whether or not the onset of enzyme leakage was reflected in structural alterations. For these reasons, perfusion was terminated in groups of livers perfused at 43°C for 15, 30, 45, 60, 75 or 90 min. These were compared with livers perfused for 90 min at 37°C (Fig. 10). Enzyme leakage and bile production indicated damage after 45 min (Figs. 11, 12, 13, 14, 15). This was earlier than changes could be detected by light microscopy, where significant damage was not evident until 75 min (Fig. 16). This data represents results from 40 perfused livers. The changes were usually expressed as severe dissociation and necrosis of hepatocytes typical of the 90 minute/43°C groups. Centrilobular coagulation necrosis, indistinguishable from that observed in earlier intact rats after heatstroke (7) was also detected in the 75 min group (Fig. 17).

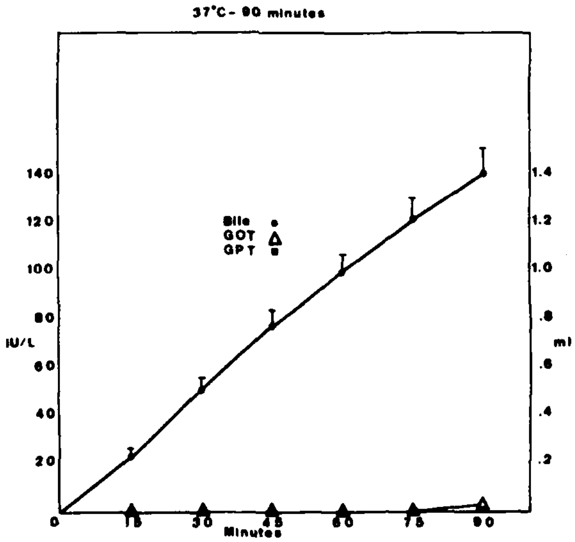

Figure 10. Bile production and release of GPT and GOT from control livers perfused at 37°C for 90 min.

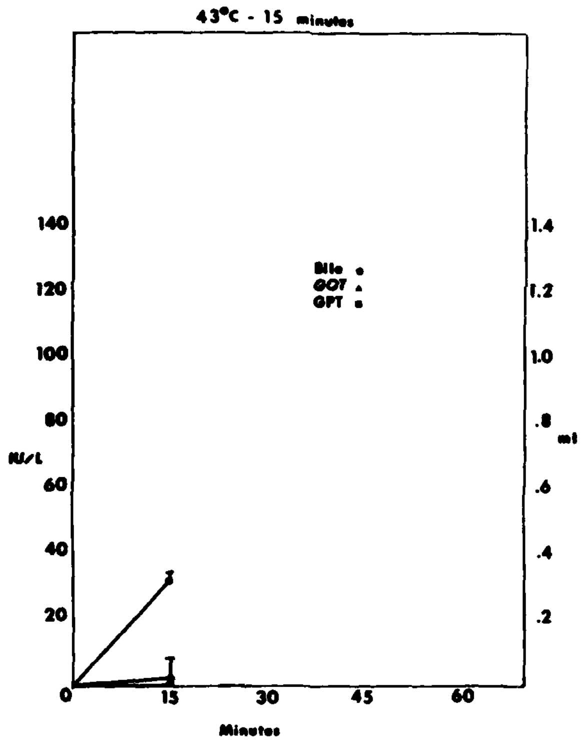

Figure 11. Bile production and release of GPT and GOT after 15 min at $43^{o}C$

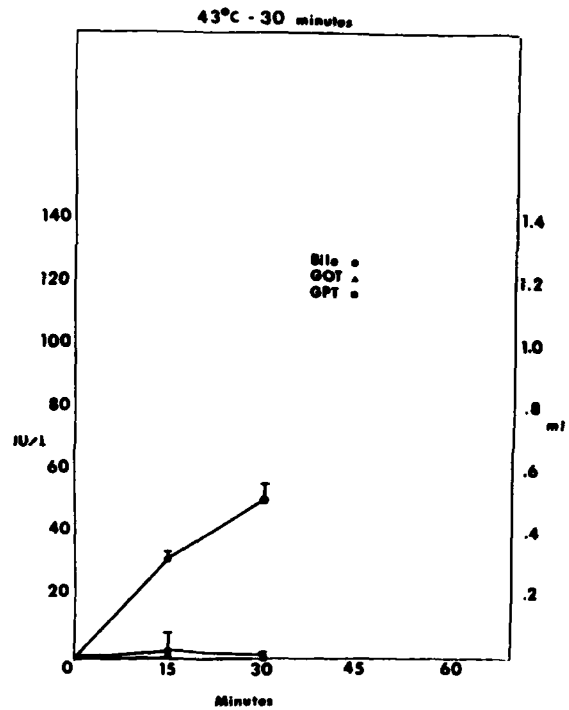

Figure 12. Bile production and release of GPT and GOT after 30 min at $43^{o}C$

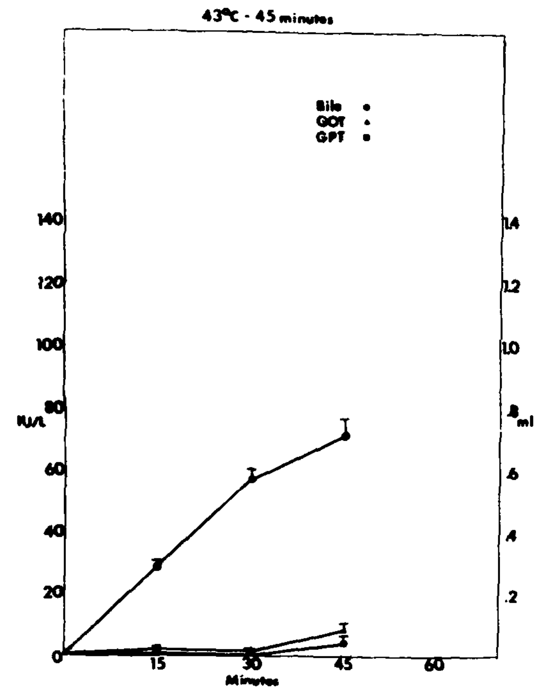

Figure 13. Bile production and release of GPT and GOT after 45 min at 43°C

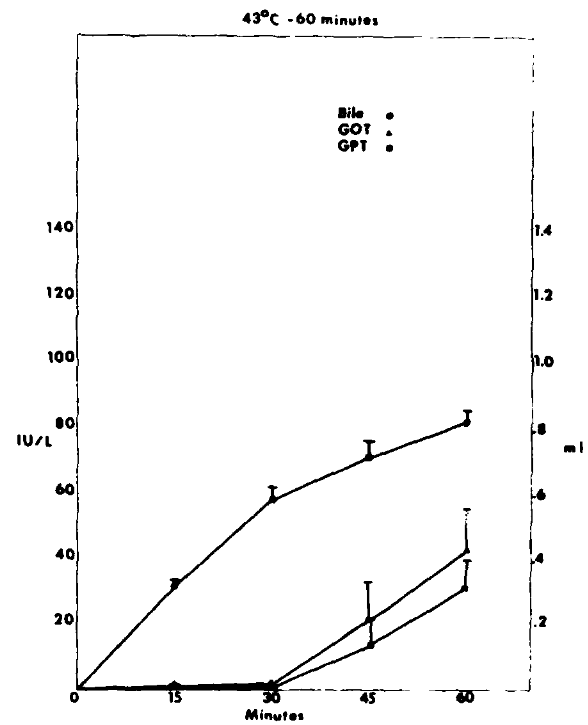

Figure 14. Bile production and release of GPT and GOT after 60 min at 43°C

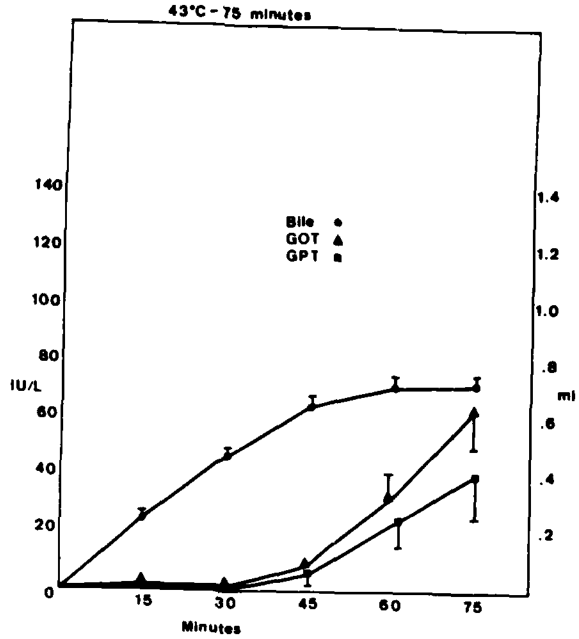

Figure 15. Bile production and release of GPT and GOT after 75 min at 43°C

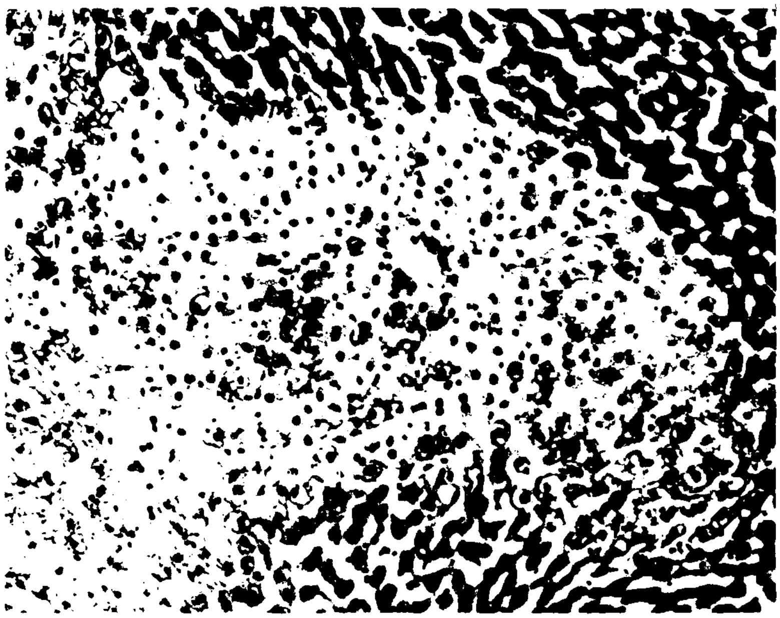

Figure 16. Light micrograph of rat liver perfused for 75 min at 43°C

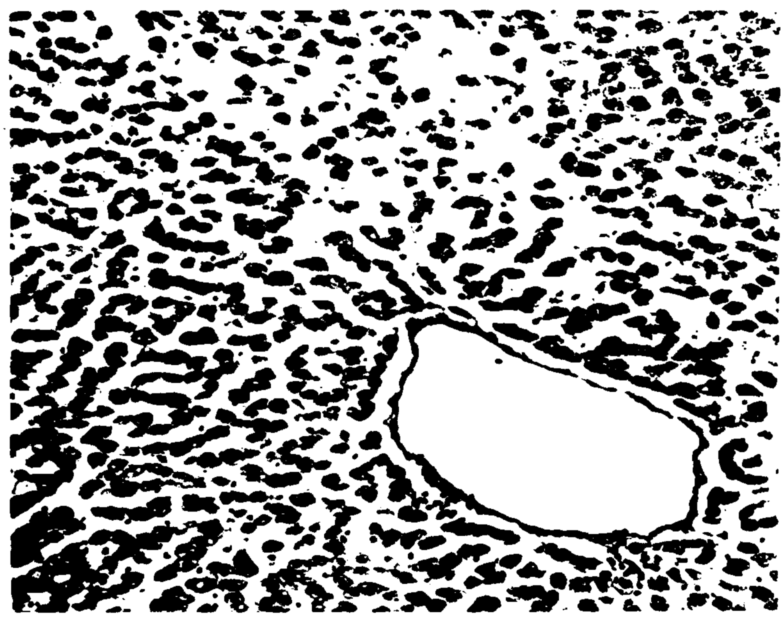

Figure 17. Light micrograph of rat liver perfused for 75 min at 43°C

Since these alterations occurred in spite of adequate oxygen and perfusion, the effects were attributed to heat and not ischemia.

Presentations:

Bowers, W. D., R. Hubbard, D. Wagner, P. Chisholm, M. Murphy, I. Leav, M. P. Hamlet and J. T. Maher. Hepatic integrity at different heat loads. Federation of American Societies for Experimental Biology, Dallas, TX, 1-10 April 1979. Fed. Proc. 38:1055, 1979.

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(81022)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA 0B 6132	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	D. Change	U	U	NA	NC	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.01.A	3A161101A91C	00	022
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*
(U) Ventilatory Control Mechanisms at High Altitude (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
012900 Physiology; 005900 Environmental Medicine; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
75 01	CONT	DA	C. In-House

17. CONTRACT/GRANT
a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER:* NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	2	63
	CURRENT 80	3	133

19. RESPONSIBLE DOD ORGANIZATION
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SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS MAHER, John T., Ph.D.
NAME: 955-2851 DA
NAME:

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U) Chronic Hypoxemia; (U) Respiratory Control System; (U) Ventilatory Muscle Training; (U) Exercise at High Altitude

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The physiologic processes which control ventilation of man at high altitude are not fully understood. The objective of this work unit is to gain new knowledge of ventilatory control, with emphasis on adaptations within the control system during exposure to chronic hypoxemia, as experienced during sojourn at high terrestrial altitudes. A thorough understanding of this aspect of altitude physiology is essential in defining new approaches for enhancing adaptation of the soldier to high terrestrial elevations.

24. (U) An integrated program is under way to analyze contributions of both the carotid body and medullary chemoreceptors to the ventilatory adaptions of man to hypocapnic hypoxia, including interactions between the two chemoreceptors. Studies are also being carried out to determine contributions of the peripheral and central chemoreceptors to the increase in ventilation during muscular exercise exceeding the anaerobic threshold, as would be seen frequently at high altitude.

25. (U) 78 10 - 79 09 (1) Ventilatory muscle training has been shown to be effective in soldiers in inducing markedly increased ventilatory muscle endurance. This increased endurance is associated with changes in the chemical and neural regulation of breathing and operates to improve the defense of pulmonary ventilation in the face of inspiratory resistive loading and hypercarbia; (2) Available algorithms for correcting P_{O2}, P_{CO2}, and pH for temperature and for calculating S_{O2}, CO_2, P_{50}, base excess, HCO_3^- and C_{CO2} from measured independent variables were analyzed in a critical review; (3) A versatile computer program, utilizing table-driven programming, was developed to apply the best available algorithms for calculating and correcting blood-gas and acid-base variables.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element: 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH

Project: 3A161101A91C In-House Laboratory Independent Research

Work Unit: 022 Ventilatory Control Mechanisms at High Altitude

Study Title: Ventilatory Muscle Training and Ventilatory Control During Loaded Breathing

Investigators: David E. Leith, M.D., Ronald A. Gabel, M.D., Vladimir Fencl, M.D., Henry Feldman, Ph.D. and Beverly Philip, M.D.

Background:

The effectiveness of a military operation may be limited by inability of the troops to function in a hostile environment. Such limiting environments are found at high terrestrial altitudes and in the presence of incapacitating chemical or biological agents. In these settings, the requirement exists for the soldier to wear protective devices which add resistive loads at the airway.

Human exercise capacity is decreased when the resistance to breathing is increased, for example by oxygen masks or gas masks or by dense gases (1,2). The early cessation of exercise under these circumstances is associated with relatively low ventilation and high CO_2 levels. It has not been understood whether or how much this should be attributed to fatigue of the breathing muscles due to increased work of breathing, or to behavior of the respiratory control system under conditions of heavy exercise and loaded breathing.

Endurance of the ventilatory muscles can be increased by suitable training (3,4). If exercise performance is limited by fatigue of the breathing muscles, ventilatory muscle training might have the potential to improve whole-body exercise performance during loaded breathing. Little is known, however, about changes which might be induced in the ventilatory control system by substantial alterations in the ventilatory effector system. If behavior of the respiratory control center is not fundamentally changed by ventilatory muscle training, neural efferent activity for a given level of afferent activity might be the same before and after ventilatory muscle training, resulting in a greater ventilatory response to a given physiologic stimulus after training. Alternatively because of substantial feedback of proprioceptive information regarding adequacy of ventilation, neural efferent traffic from the respiratory centers may be decreased

after ventilatory muscle training, such that the ventilatory response to a given physiologic stimulus after training is equal to or less than that before training. But regardless of what those relationships prove to be in the unfatigued state, we think it likely that in situations which cause fatigue of the ventilatory muscles, increase in their endurance would delay the onset of fatigue and prolong the ability to continue.

In this study, two experiments have been designed to answer the questions above. The first experiment examined the ventilatory response to carbon dioxide before and after ventilatory muscle training, with and without added inspiratory resistance. The second experiment will examine exercise tolerance and the ventilatory response to exercise, with those same interventions.

The fist experiment has been completed and data analysis and drafting of two publications are nearly complete. Results are detailed in prior annual reports. In outline, we found the following:

1) The severe program of ventilatory muscle training was well-tolerated by the subjects and caused a large and statistically significant mean increase of 28% in ventilatory muscle endurance (as measured by the capacity for long-sustained high levels of voluntary normocarbic hyperpnea).

2) The trained subjects had small but statistically significant increases in chemical control of breathing, i.e., ventilatory responses to CO_2, with or without added resistance, when compared with control subjects (e.g., an upward shift of the $\dot{V}_E$-$PACO_2$ curve of 2.5 L/min, with no change in slope);

3) The trained subjects showed small but statistically significant differences in the neural regulation of breathing compared with control subjects.

The most important of these differences are greater mean inspiratory flow and a greater fraction of time spent in inspiration under any given conditions (Figure 1A and 1B).

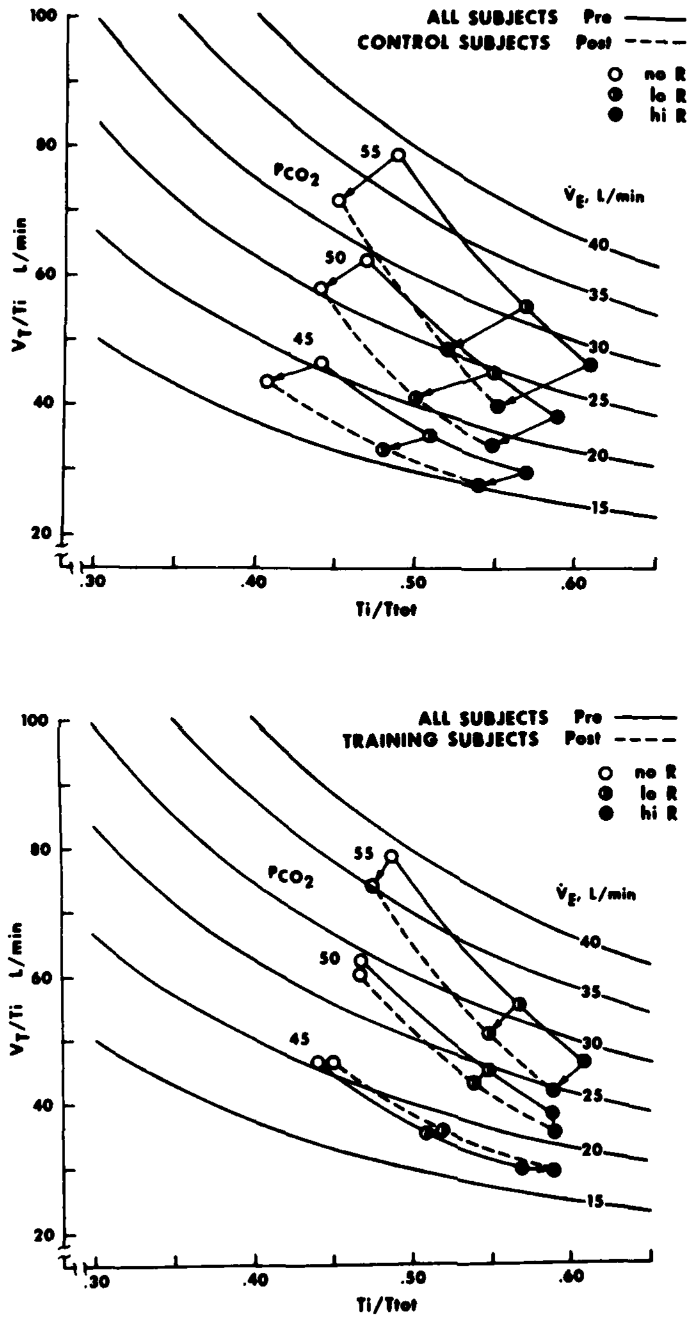

Figure 1A and 1B. Effects of CO_2 and added inspiratory resistance on the relationships between mean inspiratory flow (V_T/T_i) and the fraction of time spent in inspiration (T_i/T_{tot}). Pre-training data for all subjects, solid lines; post-training-period data, dashed lines. A, control subjects, upon remeasurement, decreased both V_T/T_i and T_i/T_{tot} under all conditions; this is ascribed to adaptation (habituation). B, trainers, in contrast, maintained V_T/T_i and increased T_i/T_{tot} at near-normal CO_2 levels after training. Thus their ventilations, with or without added resistance, were slightly greater at a P_{CO2} of 45 mm Hg after training than before, but the decrement in ventilation with the addition of loads was not different.

The greater flow could result from changes which are either central (i.e., an increase in intensity of neural activity) or peripheral (i.e., a greater muscle output, after training, in response to the same motor neural activity) or both. The increase in T_i/T_{tot} must be centrally organized and therefore represents a change in neural control.

Both of these results of training have the effect of better defending $\dot{V}_E$ in the face of added CO_2 and breathing loads. The resistances used are characterized in Figure 2.

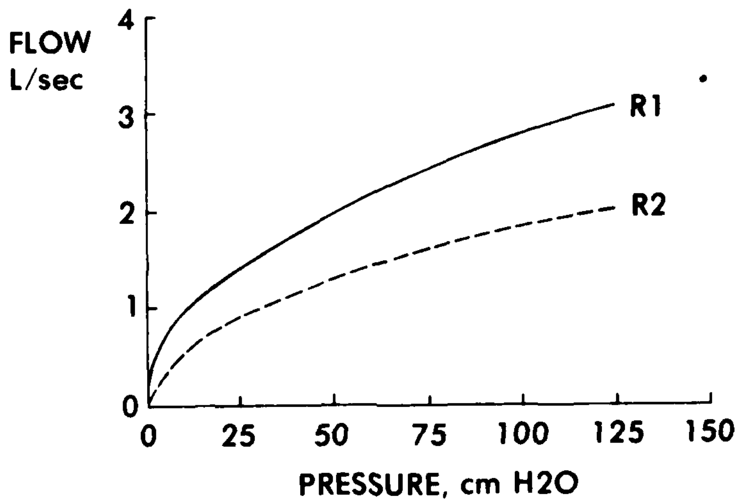

Figure 2. Pressure-flow curves for resistances used to load inspiration.

Provisional conclusions are that the training program is feasible and effective in increasing ventilatory muscle endurance, and that such training results in better defense of ventilation in the face of increased CO_2 levels combined with moderate to severe inspiratory resistive loads. A part of this defense includes changes in neural regulation of breathing, i.e., the timing of central inspiratory activity.

Progress:

During FY 1979 we have proceeded with data analysis and drafting of two manuscripts for the Phase I study. The decision to split the work into two reports was based on the fact that the initial (pretraining) study of 13 subjects was, by itself, a satisfactory description of normal respiratory control responses to combination of CO_2 and added inspiratory resistance, and the fact that the control and the training aspects of this big complex study obscured one another when combined in a single presentation.

Our analytical work this year has concentrated on the relationships among tidal volume (V_T) and the times of inspiration and expiration (T_i, T_e). Computer processing of the data provided the plot shown in Figure 3.

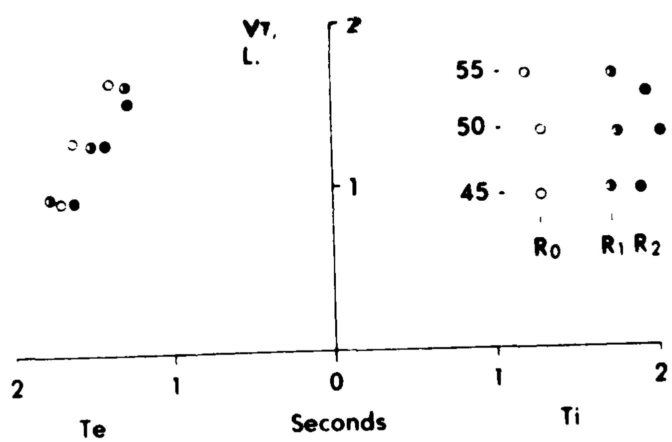

Figure 3. Tidal volume and the durations of inspiration and expiration in 8 awake normal subjects during CO_2 breathing at 3 elevated levels (45, 50, and 55 mm Hg end-expired P_{CO2}) with and without either of two levels of added inspiratory resistance. Adding resistance increases T_i without changing V_T or T_e; this is true at any given level of end-expired CO_2, and the increments in T_i are equal, that is independent of P_{CO2}. Increasing CO_2 increases V_T and decreases T_e without changing T_i; this is true at any given level of external resistance, and the changes of V_T and of T_e are equal, that is, independent of added resistance.

(Data here are for the 8 training subjects; the pooled plot for all 13 subjects is not yet available). The significance of these findings is best understood by reference to the influential work of Clark and von Euler (5), in which the responses of awake men to CO_2 were shown to be an increase in tidal volume (V_T) with no change in time (the so-called "range 1") up to V_T 2 or 3 times resting. Our results confirm these observations. But we also see that inspiratory resistance increases T_i without increasing T_e, and confirm findings of others that increasing CO_2 and V_T are associated with no change in T_i but with decreasing T_e (6,7). All of these are incompatible with Clark and von Euler's conclusions. With combinations of CO_2 and inspiratory resistance, we see that V_T is constant while T_i changes. Here, it does not appear that the termination of inspiration in awake men is set by a single fixed central timing mechamism as suggested by Clark and von Euler. The constancy of V_T under these circumstances suggests volume feedback, since it seems unlikely that the balance among added inspiratory resistive load, increased central inspiratory excitation (as indicated by the increased pressures measured at the airway 0.1 sec after the beginning of an occluded inspiration) and increased T_i would otherwise arrive at the same V_T. If it is true that there is volume-feedback control of V_T, then vagal afferents from lung stretch receptors are a probable pathway, and man should not be likened to a vagotomized animal with regard to control of V_T and T_i. Furthermore, the volume threshold for termination of inspiration appears to be CO_2-dependent and time-independent, V_T increasing by about 60 ml for each mm Hg rise in P_{CO2} (in the range of 45 to 55 mm Hg), nearly uninfluenced by added resistive loads and independent of T_i. Again, both of these behaviors (CO_2-dependence and time-independence of the volume threshold) are incompatible with Clark and von Euler's views.

We see that T_i and T_e, respectively, can be independently increased by resistive loads and decreased by increasing CO_2. Thus, these two stimuli can have similar effects on the intensity and dissimilar effects on the timing of the respiratory center output, and those two aspects of control are therefore not locked together by a single timing-intensity function.

These findings add to basic science knowledge of the control of breathing in awake normal humans, entirely aside from our primary experimental goals.

Publications:

Leith, D. E., B. Philip, R. Gabel, H. Feldman and V. Fencl. Ventilatory muscle training and ventilatory control. Am. Rev. Resp. Dis. 119:99-100, 1979.

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Program Element: 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH

Project: 3A161101A91C In-House Laboratory Independent Research

Work Unit: 022 Ventilatory Control Mechanisms at High Altitude

Study Title: Algorithms for Calculating and Correcting Blood-Gas and Acid-Base Variables

Investigators: Ronald A. Gabel, M.D.

Background:

With increasing availability of computers and programmable calculators, many computations previously performed on blood-gas data with analog devices, such as slide rules (1), nomograms (2,3,4,5), and line charts (4,6,7), can now be carried out more conveniently using digital techniques. For this, one needs numeric algorithms to represent certain physical and chemical relationships in the blood.

Progress:

To permit rational selection from among the many available algorithms for calculating and correcting blood-gas and acid-base variables, we undertook a critical analysis and comparison of the available algorithms. Following is an abstraction of major points from the critical review:

I. Oxygen Hemoglobin Equilibrium Curve (OHEC)

A. The Standard OHEC

The sigmoid curve describing relationships between P_{O2} and S_{O2} in blood is usually mathematically modeled from 38 data pairs reported by Severinghaus in 1966 (1). These matching values of S_{O2} and P_{O2} represent the OHEC for normal adult human blood at 37°C, pH = 7.40, and P_{CO2} = 40 torr.

The algorithm of Ruiz for estimating S_{O2} from P_{O2} (Table 1) fits the data of Severinghaus better than other available equations (7). The range of residual errors in S_{O2} that result when calculated values are compared with the original data is -0.15 to 0.19 percent saturation, with a root mean square, a measure of the "average error" from applying the algorithm, of 0.07 percent saturation.

TABLE 1

1. Ruiz's Algorithm for Calculating S_{O2} (S) from P_{O2} (P) According to the standard OHEC:

$$S = 99.95-100/(1+((P+7)/33.7)^{3.3})$$
$$-0.5/(1+((P-130)/35)^{2})+0.45/(1+((P-68)/12)^{6})$$
$$-0.5/(1+((P-35)/3)^{4})-0.5/(1+((P-15)/4)^{4})$$
$$+0.35/(1+((P-26)/3)^{6})+0.2/(1+((P-53)/8)^{4})$$
$$-0.4/(1+((P-40)/0.9)^{4})-0.2/(1+((P-200)/65)^{8})$$
$$+0.4/(1+((P-9)/3)^{2})$$

2. Lutz's Algorithm for Calculating P_{O2} (P) from S_{O2} (S) in the range S = 1-20%:

$$P = (((a_2/2)^2+a_1S)^{0.5}-a_2/2)/a_1$$

where $a_1 = 0.062$
$a_2 = 0.351$

3. Tien's Algorithm for Calculating P_{O2} (P) from S_{O2} (S) in the range 20-97.5%:

$$P = \exp_e(a_0+a_1x+a_2x^2+...+a_nx^n)$$

where x is the natural logarithm of S/(100-S) and

$a_0=3.282 \times 10^0$
$a_1=3.909 \times 10^{-1}$
$a_2=-6.580 \times 10^{-4}$
$a_3=-9.348 \times 10^{-3}$
$a_4=-3.805 \times 10^{-3}$
$a_5=2.856 \times 10^{-3}$
$a_6=-3.494 \times 10^{-4}$

For estimating P_{O2} from S_{O2}, application of Lutz's low-range equation when S_{O2} is below 20 percent (Table 1) (9) and Tien's wide-range algorithm when S_{O2} is 20-97.5 percent (Table 1) (10), gives a combined root mean square of 0.10 torr and range of residual errors from -0.21 to 0.18 torr.

B. Effects of Temperature, pH, and P_{CO2} on Position of the OHEC

When developing algorithms for dealing with changes in the affinity between oxygen and hemoglobin owing to changes in temperature, pH, and P_{CO2}, it is generally assumed that these variables influence position but not shape of the OHEC (1,7,11). For S_{O2} = 5-95 percent, where this assumption is valid, P_{O2} is increased or decreased by a single multiplicative factor for any combination of temperature, pH, and P_{CO2} deviating from the standard 37°C, 7.40, and 40 torr. Hence, S_{O2} of blood having nonstandard temperature, pH, and P_{CO2} can be approximated from the standard OHEC by first calculating a virtual P_{O2} (P_v) that would exist if temperature, pH, and P_{CO2} were made standard:

$$P_v = P_m \left(\exp_{10}(-0.024(T-37) + 0.40\,(pH-7.4) + 0.06(\log_{10}40 - \log_{10}P_{CO2}))\right) \qquad (1)$$

where T is body temperature, P_m is P_{O2} at body temperature, and pH and P_{CO2} are values corrected to body temperature (4,7,8,11). The value of P_v can then be substituted for P in Ruiz's algorithm (Table 1) to compute the S_{O2} expected at the observed values of P_{O2}, P_{CO2}, pH and temperature.

II. Anaerobic Temperature Corrections

With changes in temperature come alterations in both solubility of gases and dissociation constants of ionizable solvents and solutes. Therefore, P_{O2}, P_{CO2}, and pH of blood change as temperature is anaerobically altered. With cooling, pH is increased, P_{CO2} and P_{O2} decreased; with warming, the opposite is true.

A. pH

Rosenthal reported that pH of whole blood decreases 0.0147 as temperature is elevated 1°C; that is, $\Delta pH/\Delta T = -0.0147$ (12). Adamsons and colleagues subsequently showed that $\Delta pH/\Delta T$ is not constant but is dependent upon pH and carbon dioxide concentration (C_{CO2}) of the blood (13). They reported that $\Delta pH/\Delta T = -0.0146 - 0.005\,(pH_{38} - 7.4) + (5 \times 10^{-5})(C_{CO2} - 20)$ where pH_{38} is pH at 38°C. Severinghaus (1) approximated this with $\Delta pH/\Delta T = -0.0146 - 0.0065\,(pH_{38} - 7.4) + (3 \times 10^{-5})$ (BE) and pointed out that the final term may be ignored,

because the error in pH correction owing to abnormal BE would be only $\pm$ 0.006 in the extreme case when ΔT is $\pm$ 10°C and BE is $\pm$ 20 mEq/L. The correction per degree centigrade will be insignificantly different if temperature of the electrode is 37 rather than 38°C. Therefore, pH at T°C can be calculated from:

$$pH_T = pH_{37} - (T-37)(0.0146+0.0065(pH_{37}-7.4)) \tag{2}$$

B. $\underline{P_{CO2}}$

When blood is anaerobically warmed or cooled, C_{CO2} remains constant (1,6); therefore, temperature-dependent alterations in P_{CO2} result from changes in pH, dissociation constants, and solubility of carbon dioxide. Temperature correction for P_{CO2} follows an exponential relationship (1,4,6,14): $P'_{T1}/P'_{T2} = \exp_{10}\ (f'\ (T_1-T_2))$ where P'_{T1} and P'_{T2} are P_{CO2}'s at different temperatures.

Although Bradley, Stupfel, and Severinghaus reported theoretical values for f' ranging from 0.0175 to 0.0222, depending upon pH and temperature (6), Nunn and colleagues experimentally found that f' = 0.019 for wide ranges of P_{CO2} (18.6-70.7 torr) and temperature (18.0-36.5°C) (14). Severinghaus subsequently advocated use of 0.019 for temperature correction near 37°C, with the admonition that correction factors for lower body temperatures (less than 30°C) will be too large, especially if blood pH is also low (1). For body temperatures of 30–40°C, the following algorithm can be used to correct P_{CO2} for differences in temperature between the measuring electrode and the body:

$$P'_T = P'_{37}\exp_{10}(0.019)(T-37)) \tag{3}$$

where P'_T is P_{CO2} at body temperature (T°C) and P'_{37} is P_{CO2} measured at 37°C.

C. $\underline{P_{O2}}$

Change in the P_{O2} of blood with anaerobic cooling or warming in the midrange of the OHEC is caused primarily by an alteration in the affinity between oxygen and hemoglobin; that is, by change in position of the OHEC (1). For S_{O2} up to about 75 percent, the P_{O2} correction for temperature is thus

dependent not only on changes in position of the OHEC with temperature and pH (equation 1), but also on changes in pH with temperature (equation 2). However, after appropriate portions of these two equations are mathematically combined, the terms having to do with the dependence of $\Delta pH/\Delta T$ on pH and BE may be ignored, since they would produce a maximum change in $\Delta \log_{10} P_{O2}/\Delta_T$ of only $\pm$ 0.0018 ($\pm$ 0.4 percent error in the ratio of P_{O2}'s at different temperatures, P_T/P_{37}, per degree centigrade) for variations in pH of $\pm$ 0.5 and in BE of $\pm$ 20 mEq/L. Hence, for midrange of the OHEC, $\Delta \log_{10} P_{O2}/\Delta T = 0.031$ (1).

This assumes constancy not only of oxygen concentration (C_{O2}) but also of S_{O2} during anaerobic temperature change. Saturation values greater than 75-80 percent (P_{O2} above 40-45 torr) cannot, however, be assumed to remain constant during change in temperature. When blood is cooled, some dissolved oxygen combines with hemoglobin, because during cooling the increase in affinity between hemoglobin and oxygen is dominant over the increase in solubility of oxygen in blood (1,14,15). The resulting slight elevation in S_{O2} with cooling becomes more influential near the top of the OHEC, where small increases in S_{O2} result in large increases in P_{O2}. Therefore, at P_{O2} values greater than 40-45 torr, a reduction in temperature produces proportionally less decrease in P_{O2} than at lower P_{O2}'s (Figure 1).

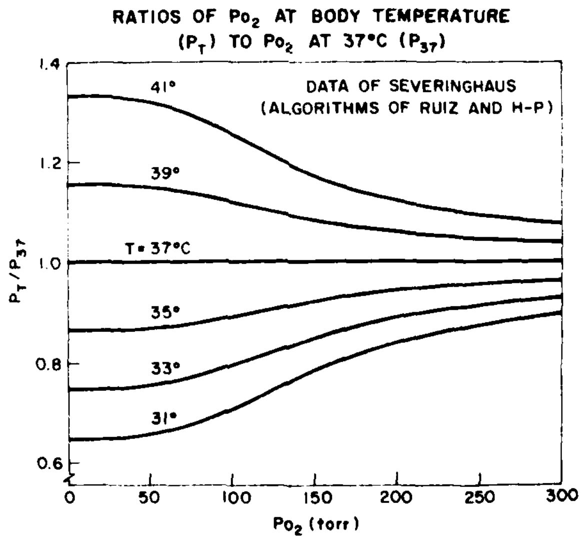

Figure 1. To correct P_{O2} from 37°C to body temperature, the measured value of P_{O2} is multiplied by the calculated ratio of P_{O2} at body temperature (P_T) to that at 37°C (P_{37}). For body temperature higher or lower than 37°C, the ratio approaches unity as P_{O2} (P_{37}) increases.

Variable $\Delta \log_{10} P_{O2}/\Delta T$ with increasing P_{O2} and S_{O2} is accounted for in the data of Severinghaus (1) that underlie the algorithm reported by Ruiz and colleagues (8) for calculating P_{O2} at $T^{o}C$ (P_T) from P_{O2} measured at $37^{o}C$ (P_{37}):

$$P_T = P_{37}(\exp_{10}((T-37)(0.0265/((P_{37}/146)^3+1)+ 0.0007/(0.02(P_{37}-230)^2+1)+0.0047))) \quad (4)$$

An algorithm using S_{O2} (S) rather than P_{O2} comes from a commercial source (HP-67/HP-97 Users' Library Solutions. Pulmonary. Hewlett-Packard, 1000 N. E. Circle Boulevard, Corvalis, OR 97330):

$$P_T = P_{37}(\exp_{10}((T-37)(3130-62.5(S)+0.312008(S^2))/ (100{,}000-1{,}993(S)+9.9313(S^2)))) \quad (5)$$

When S_{O2} = 1-99.5 percent, factors P_T/P_{37} computed from equations 4 and 5 differ by less than 0.1 percent per degree centigrade change in temperature.

Severinghaus has recently published his own algorithm for this correction (16):

$$P_T = P_{37}(\exp_e((T-37)(0.013+0.058/(1+0.243(P_{37}/100)^{3.88})))) \quad (6)$$

Correction factors P_T/P_{37} calculated from this equation are within $\pm$ 0.4 percent per degree centigrade of those calculated from equation 4 or 5. Therefore, the three algorithms are comparable when accounting for small temperature variations.

From data of Nunn and colleagues (14), Kelman and Nunn (4) developed another algorithm for calculating P_{O2} at a temperature other than that at which P_{O2} is measured:

$$P_T = P_{37}(\exp_{10}((T-37)(0.0052+0.0268(1-\exp_e(-0.3(100-S)))))) \quad (7)$$

Values of P_T/P_{37} from equation 7 differ with those from equations 4,5, and 6 by as much as 1.6 percent per degree centigrade (maximum differences at P_{O2} = 110 - 130 torr).

III. Base Excess (BE)

Gershwin and colleagues (17) in 1974 developed an iterative digital technique for calculating BE from the point of intersection between a mathematically-modeled blood buffer line and the base excess curve on Siggaard Andersen's acid-base nomogram (2) (Figure 2). Slope of the buffer line is approximated by:

$$s = -1.16(\exp_e(0.0204(\mathrm{Hb})-0.01434(\mathrm{BE}))) \tag{8a}$$

pH at which the buffer line intersects the base excess curve (Figure 2) is found by simultaneously solving equations representing the two lines, each expressed as a function of $\Delta \log_{10} P_{CO2}/\Delta T$ and pH:

$$\mathrm{pH}' = (-B-(B^2-4AC)^{0.5})/2A \tag{8b}$$

where
$$A = s+0.77$$
$$B = \log_{10}P_{CO2}-s(\mathrm{pH})-7.55-7.165(s+0.77)$$
$$C = -7.165(\log_{10}P_{CO2})+7.165(s)(\mathrm{pH})+7.55(7.165)+0.058$$

To calculate BE, the value of pH' is substituted in an empiric equation for the base excess curve expressed as a function of pH alone:

$$\mathrm{BE} = 59.4(\log_{10}(3.36(\mathrm{pH}'-0.1))) \tag{8c}$$

In practice, an initial estimate of 0 mEq/L is substituted for BE in equation 8a. Subsequent estimates obtained from 8c are then reintroduced into 8a until equations 8a, b, and c have been sequentially applied three times.

Gershwin's algorithm probably provides the best available method for calculating BE using small programmable calculators. When BE = -15 to + 10 mEq/L, P_{CO2} = 20 – 80 torr, pH - 7.2 - 7.6, and Hb = 10 - 20 gm/100 ml, it gives values for BE that are within $\pm$ 0.8 mEq/L of values read from the Severinghaus Blood Gas Calculator (1).

In vitro, BE is not affected by changes in P_{CO2}. However, *in vivo*, where bicarbonate distributes itself in interstitial fluid as well as in blood plasma, BE exhibits a different relationship to pH and P_{CO2} than in the test tube (18, 19,20). Therefore, Severinghaus has proposed that the "*in vivo* BE" (BE_3) be read from

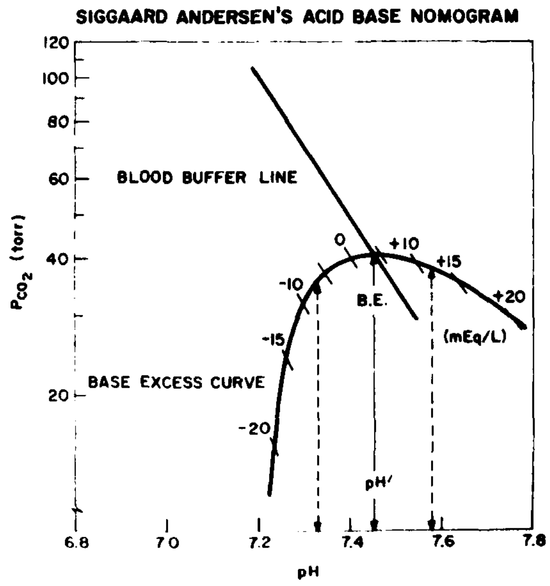

Figure 2. To calculate BE using Gershwin's algorithm, slope of the blood buffer line is approximated by substituting a value for Hb and an estimate for BE in an empirically-derived equation (8a). *Equations representing the blood-buffer line* (rectilinear) and the base excess curve (hyperbolic) are simultaneously solved for pH, eliminating the P_{CO2} terms. The resulting value, pH', is then substituted in equation 8c, which mathematically represents reflection of the base excess curve on the horizontal axis.

Siggaard Andersen's alignment nomogram at 3 gm/100ml, an "average" hemoglobin concentration in the extracellular fluid (5). When bicarbonate and carbon dioxide re-equilibrate and redistribute as P_{CO2} in blood is altered in vivo, the BE_3 remains relatively constant, signifying constancy of the metabolic acid-base state. Severinghaus' algorithm for approximating BE_3 is:

$$BE_3 = 37(\exp_e((pH-7.4+0.345(\log_e(P_{CO2}/40)))/(0.55-0.09(\log_e(P_{CO2}/40))))-1) \quad (9)$$

For BE = -20 to + 15 mEq/L and P_{CO2} = 10 - 80 torr, BE_3 calculated with this equation is within ± 0.3 mEq/L of that read from a special modification of Siggaard Andersen's alignment nomogram (5).

Severinghaus (5) also reported an equation for calculating the "compensated BE_3" (BE_c) that would be expected, according to the data of Brackett and colleagues (20), after full renal compensation for prolonged hypercapnia:

$$BE_c = 15 (\log_e (P_{CO2}/40)) + 0.095 (P_{CO2}-40) \tag{10}$$

This equation, too, matches the nomogram to within ± 0.3 mEq/L for P_{CO2} up to 80 torr. Dividing equation 9 by equation 10 gives an indication of the degree of renal compensation for respiratory acidosis.

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Program Element: 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH

Project: 3A161101A91C In-House Laboratory Independent Research

Work Unit: 022 Ventilatory Control Mechanisms at High Altitude

Study Title: Calculation and Correction of Blood-Gas and Acid-Base Variables with a Versatile Computer Program

Investigators: Ronald A. Gabel, M.D., Audrey Hooper, John J. Marseglia, Jr. and Genevieve E. Farese

Background:

Data generated in the blood-gas laboratory must be refined before use in research or for clinical purposes. P_{O2}, P_{CO2}, and pH should be adjusted to body temperature, if different from that of the measuring electrodes (1). Corrections should be made for measuring artifacts, such as the "suspension effect" for pH and "stirring artifact" for P_{O2} (2,3). An estimate of the metabolic component of acid-base balance, either base excess or plasma bicarbonate concentration, is often derived. Furthermore, oxygen saturation is sometimes calculated from measured values of P_{O2}, P_{CO2}, pH, and body temperature. Such calculations and corrections have traditionally been carried out with slide rules, nomograms, and line charts.

Progress:

We have developed a versatile computer program for carrying out useful calculations and corrections of blood-gas and acid-base variables. The program is written in Fortran IV to facilitate use on a wide variety of computers.

Input can be any combination of the following measured values: P_{O2}, P_{CO2}, pH, oxygen saturation, hemoglobin concentration, body temperature, and temperature of the measuring electrodes. If the P_{O2} electrode has been calibrated with gas standards and if readings for P_{O2} are to be corrected for "stirring artifact," required input includes values for P_{O2} in air and in water tonometered with air at temperature of the electrode (2,3). If values for blood pH are to be corrected for the "suspension effect," the value to be added to each pH reading must be specified (2,3).

Output can be any combination of the following:

1. P_{O2}, P_{CO2}, and pH corrected to body temperature, according to the algorithm of either Ruiz et al. (4) or Kelman and Nunn (5) for P_{O2}, of Nunn et al. for P_{CO2} (6), and of Adamsons et al. for pH (7);

2. An estimate of S_{O2} from P_{O2}, P_{CO2}, pH, and body temperature, according to algorithms of Kelman (8) (to calculate a virtual P_{O2} for the in vivo conditions of P_{CO2}, pH, and temperature) and Ruiz et al. (4) (to calculate S_{O2} from the virtual P_{O2});

3. An estimate of oxygen concentration (C_{O2}) calculated from P_{O2}, S_{O2}, and Hb, according to the following equation: $C_{O2} = 0.003\ (P_{O2}) + 0.0136\ (S_{O2})\ (Hb)$;

4. Estimates of plasma bicarbonate (HCO_3^-) and carbon dioxide concentrations (C_{CO2}) from pH and P_{CO2}, using the Henderson-Hasselbalch equation;

5. An estimate of base excess (BE) from pH, P_{CO2}, and Hb, according to the algorithm of Gershwin et al. (9);

6. An estimate of "in vivo" base excess (BE_3) and of "compensated base excess" (BE_c), using equations of Severinghaus (10); also the quotient BE_3/BE_c, which reflects the degree of renal compensation for prolonged respiratory acidosis (10); and

7. Estimates of P_{O2} at half saturation, both in vitro (P_{50}) and in vivo (P'_{50}) (11).

A special feature of the program is the ease with which the user can select operations to be carried out from among those available. Key to the versatility is the concept of "table-driven" programming (12,13). Users have the option of creating and storing as many driving tables as they wish, each table controlling the input and output for a specific task of blood-gas correction or calculation. Details of each task are entered once, through interaction of the user with the setup program, using a computer terminal having either typewritten output or CRT (cathode ray tube) display. The table controlling the task is given a unique name, with which the table can be recalled at any time.

Further veratility is offered by a "learner mode" that can be selected as an aid to setting up a driving table or executing a task. This mode, which provides detailed step-by-step instructions, is designed for the novice who has never used the program before, or for the experienced user who wants to review the

operating procedures. Both modes, "learner" and "user," are designed to be sufficiently self-explanatory that persons with little or no experience can set up new driving tables and execute tasks from existing tables.

Application of the program is illustrated in the tables that follow. Tables 1A, 1B, 1C, and 2 show interaction between the user and the computer in creating a driving table and in entering data, respectively, and Table 3 shows the resulting output.

TABLE 1A

Interaction Between User and Program in Setting Up
Driving Table: Specifying the Inputs
(The User's Entries are Underlined)

RUN SETUP
THIS PROGRAM HAS A LEARNER MODE AND A USER MODE.
THE LEARNER MODE PROVIDES MORE DETAILED EXPLANATIONS. DO YOU WANT THE LEARNER MODE? Y/N:

N
ENTER USER ID: GENV
ENTER NAME OF DRIVING TABLE: STANDARD
PO2 CORRECTION FOR STIRRING? Y/N: Y
PH CORRECTION FOR SUSPENSION? Y/N: Y
POSSIBLE INPUTS:
TEMP, PO2, PCO2, PH, SO2, HB, CCO2, C"O2
ENTER INPUT NAME: TEMP
ENTER INPUT NAME: PO2
ENTER INPUT NAME: PCO2
ENTER INPUT NAME: PH
ENTER INPUT NAME: Z

ARE YOU SATISFIED WITH THE INPUTS YOU HAVE CHOSEN?
Y/N
Y

TABLE 1B

Interactions Between User and Program in Setting Up Driving Table: Specifying the Calculations (The User's Entries are Underlined)

POSSIBLE CALCULATIONS:
RPO2, KPO2, PCO2, PH, BE, BE3, BEC, METC,
HCO3, CCO2, SO2, C"O2, P50, P"50
ENTER CALCULATION: RPO2
ENTER CALCULATION: PCO2
ENTER CALCULATION: PH
ENTER CALCULATION: BE
ENTER CALCULATION: BE3
ENTER CALCULATION: HCO3
ENTER CALCULATION: Z

INPUT HB IS NEEDED TO CALCULATE BE
ARE YOU SATISFIED WITH THE CALCULATIONS YOU HAVE CHOSEN? Y/N:
Y

TABLE 1C

Interaction Between User and Program in Setting Up
Driving Table: Specifying the Output Format
(The User's Entries are Underlined)

```
HOW MANY OUTPUT COLUMNS DESIRED?: 12
POSSIBLE OUTPUTS:
MEAS TEMP, MEAS PO2, CORR RPO2, CORR KPO2, MEAS PCO2, CORR
PCO2, MEAS PH, CORR PH, MEAS HB, CALC BE, CALC BE3, CALC BEC,
CALC METC, CALC HCO3, MEAS CCO2, CALC CCO2, MEAS SO2, CALC SO2,
MEAS C"O2, CALC C"O2, CALC P50, CALC P"50
ENTER OUTPUT NAME: MEAS TEMP
NUMBER OF DECIMAL PLACES? (1 TO 5): 1
ENTER OUTPUT NAME: MEAS PO2
NUMBER OF DECIMAL PLACES? (1 TO 5): 1
ENTER OUTPUT NAME: MEAS PCO2
NUMBER OF DECIMAL PLACES? (1 TO 5): 1
ENTER OUTPUT NAME: MEAS PH
NUMBER OF DECIMAL PLACES? (1 TO 5): 3
ENTER OUTPUT NAME: MEAS HB
NUMBER OF DECIMAL PLACES? (1 TO 5): 1
ENTER OUTPUT NAME: CORR RPO2
NUMBER OF DECIMAL PLACES? (1 TO 5): 1
ENTER OUTPUT NAME: CORR PCO2
NUMBER OF DECIMAL PLACES? (1 TO 5): 1
ENTER OUTPUT NAME: CORR PH
NUMBER OF DECIMAL PLACES? (1 TO 5): 3
ENTER OUTPUT NAME: CALC SO2
NUMBER OF DECIMAL PLACES? (1 TO 5): 1
ENTER OUTPUT NAME: CALC BE
NUMBER OF DECIMAL PLACES? (1 TO 5): 1
ENTER OUTPUT NAME: CALC BE3
NUMBER OF DECIMAL PLACES? (1 TO 5): 1
ENTER OUTPUT NAME: CALC HCO3
NUMBER OF DECIMAL PLACES? (1 TO 5): 1
ARE YOU SATISFIED WITH THE TABLE SETUP?  Y/N : Y
TT7 -- STOP
>
```

TABLE 2

Interaction Between User and Program in Executing the Program for Calculating and Correcting Blood-gas and Acid-base Variables: Entering the Data (The User's Entries are Underlined)

```
RUN EXECUTE
THIS PROGRAM HAS A LEARNER MODE AND A USER MODE.
THE LEARNER MODE PROVIDES MORE DETAILED EXPLANATIONS.  DO
YOU WANT THE LEARNER MODE? Y/N:

N
ENTER USER ID: GENV
ENTER NAME OF DRIVING TABLE: STANDARD
ENTER AIR PO2: 150.6
ENTER WATER PO2: 147.4
ENTER VALUE TO CORRECT PH: .01
ENTER ELECTRODE TEMPERATURE: 37
ENTER TITLE OF OUTPUT TABLE: EXAMPLE

ENTER BODY TEMPERATURE: 37
ENTER PO2: 95.5
ENTER PCO2: 39.1
ENTER PH: 7.402
ENTER HB: 14.3
DO YOU WANT THIS LINE IN THE OUTPUT TABLE?  Y/N : Y

ENTER BODY TEMPERATURE: 36.9
ENTER PO2: 68.4
ENTER PCO2: 55.7
ENTER PH: 7.368
ENTER HB: 17.4
DO YOU WANT THIS LINE IN THE OUTPUT TABLE?  Y/N : Y
```

TABLE 2 (CONTINUED)

```
ENTER BODY TEMPERATURE: 30.6
CORRECT?  Y/N : Y
ENTER PO2: 227.2
ENTER PCO2: 42.3
ENTER PH: 7.333
ENTER HB: 9.7
DO YOU WANT THIS LINE IN THE OUTPUT TABLE?  Y/N : Y

ENTER BODY TEMPERATURE: 39.5
ENTER PO2: 82.0
ENTER PCO2: 30.2
ENTER PH: 7.373
ENTER HB: 12.5
DO YOU WANT THIS LINE IN THE OUTPUT TABLE?  Y/N : Y

ENTER BODY TEMPERATURE:  Z

FOR EACH COPY OF TABLE ROLL TO TOP OF THE PAGE AND HIT RETURN.
WHEN FINISHED, ROLL TO TOP OF PAGE AND HIT CTRL/Z.
```

TABLE 3

Output Table Generated According to the
Driving Table and the Data Entered by the User

EXAMPLE

TEMP	PO2	PCO2	PH	HB	CORR RPO2	CORR PCO2	CORR PH	CALC SO2	CALC BE	CALC BE3	CALC HCO3
37.0	95.5	39.1	7.402	14.3	99.2	39.1	7.412	97.5	0.3	0.3	24.6
36.9	68.4	55.7	7.368	17.4	70.6	55.5	7.379	93.7	5.3	7.3	32.3
30.6	227.2	42.3	7.333	9.7	203.2	32.0	7.434	99.9	-2.8	-2.4	22.9
39.5	82.0	30.2	7.373	12.5	99.4	33.7	7.347	96.1	-6.4	-6.7	17.7

DATE:	08-AUG-79
TIME:	08:52:50
ELECTRODE TEMP:	37.0
SUSPENSION EFFECT:	0.010
STIRRING EFFECT:	1.039
AIR PO2:	150.6
WATER PO2:	147.4

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(81023)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OC 6128	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	H. Terminated	U	U	NA	NL	☐ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.01.A	3A161101A91C	00	023
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*

(U) Role and Significance of Endotoxin in Heatstroke (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

005900 Environment Biology; 010100 Microbiology; 02300 Biochemistry

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
78 08	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	1.0	54
	CURRENT		

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* DuBOSE, David A.

TELEPHONE: 955-2862

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: HAMLET, Murray P., D.V.M.

NAME: 955-2865 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U) Endotoxin; (U) Reticuloendothelial; (U) Tolerance; (U) Heatstroke

23. TECHNICAL OBJECTIVE.* 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The presence of endotoxin in heatstroke has been documented in man and in both dog and rat models for heatstroke. To date the significance of this association is not known. This study is designed to further understand the role and significance of endotoxin in heatstroke.

24. (U) The relationship between presence of endotoxin and severity of heat exposure will be studied in the rat heatstroke model using the limulus amoebocyte lysate test. To determine the significance of any association of endotoxin with heatstroke the study of endotoxin tolerant animals under heatstroke conditions will be undertaken. The finding of an increase in survival with tolerant animals would indicate a significant role for endotoxin in the pathophysiology of heatstroke. If animals can be protected from heatstroke by this form of tolerance, this may be indicative of an applied method by which man may be made more resistant to the effects of heatstroke.

25. (U) 78 10 - 79 09 Preliminary observations appear to indicate there are heat treatments which are suitable for possible microbial and/or endotoxin invasion from the gut. Heat treatments which resulted in an estimated average lethal dose (EALD) of 62.6% had the highest level of gram-negative invasion of the liver (67%), spleen (40%), lung (75%) and blood (25%). In addition, positive LAL test were associated with those tissues and blood samples in which gram-negative invasion was found. The level of gram-negative invasion and positive LAL tests decreased when EALD was above or below 62.6%. Invasion of the liver by gram-negative bacteria was found to be associated with shifts in the normal flora of the small intestine. Rats in which invasion of the liver was noted had significantly higher gram-negative microbial counts of the small intestine than rats experiencing no invasion after heatstroke. This work will be continued on another work unit (010).

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Project Element:	6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	023 Role and Significance of Endotoxin in Heatstroke
Study Title:	Role and Significance of Endotoxin in Heatstroke
Investigator:	David A. DuBose, M.S., Murray P. Hamlet, D.V.M., Lynn R. Trusal, CPT, MSC, Ph.D., Wilbert D. Bowers, Jr., Ph.D. and Roger W. Hubbard, Ph.D.

Background:

Endotoxin or lippopolysaccharide is known to be associated with the cell wall of gram-negative microorganisms. The release of endotoxin into the circulating blood can precipitate a series of events which may ultimately lead to a state of shock (1). Endotoxin shock and heatstroke appear to have some similarity in their clinical pictures (1,2). In addition, investigators have determined the presence of circulating endotoxin in cases of human heatstroke (3,4). For these reasons, there has been an interest as to the role and significance of endotoxin in heat related deaths.

The most widely used technique to indicate the presence of endotoxin in blood plasma is the Limulus Amoebocyte Lysate (LAL) test. Using such a procedure and the rat model of experimental heatstroke (5), the incidence of endotoxin invasion of tissues and blood plasma after heat stress has been studied. Since there are still questions as to the reliability and validity of the LAL test, the incidence of gram-negative microbial invasion has also been examined.

Progress:

Table 1 shows the control data for the presence of positive LAL tests and gram-negative microbial isolates in tissue and blood plasma samples from non-heated fasted rats. Samples for LAL testing employed a dilution and heating extraction procedure and utilized Pyrotell LAL (Associates of Cape Cod, Woods Hole, MA). The presence of gram-negative microbial isolates was determined by homogenizing diluted tissue and then making spread plates on microbiological media selective for gram-negative microorganisms. As can be seen, blood, liver

and spleen samples were consistently free of endotoxin and isolates. Lung tissue was found on occasion to have both positive LAL tests and isolates. These lung findings are not understood in the light of the normal appearance of the rats tested. Perhaps the positive LAL test of the lungs reflects the environmental condition of being housed in close approximation to voided feces and represents inhalation of microbes and/or endotoxin from the air. Proteus was identified as the isolate found in the one control lung. Though contamination of the sample cannot be completely ruled out, it did not appear likely. The finding of microbes in lung tissue may be indicative of sampling too high on the bronchial tree.

TABLE 1

Rat Tissue and Blood Control Data

	Blood	Liver	Spleen	Lung
% Microbiology*	0.0	0.0	0.0	14.3
% LAL tests≠	0.0	0.0	0.0	33.3

*Percent showing presence of gram-negative microbial isolates.

≠Percent showing presence of positive limulus amoebocyte lysate test.

Figure 1 shows the percent for positive gram-negative microbial invasion of tissues and blood in non-surviving rats after a variety of heat treatments. Rats were grouped according to estimated mean percent lethal heat dose (EM%LHD) as determined by both maximum rectal temperature and total heat area incurred. At an EM%LHD ranging between 45 and 65, the highest percent of invasion was found. Within this group, approximately 80% of the lungs, 56% of the livers, 50% of the spleens and 17% of the blood samples showd evidence of gram-negative microbial invasion. Heat treatment groups above and below this were found to have less invasion.

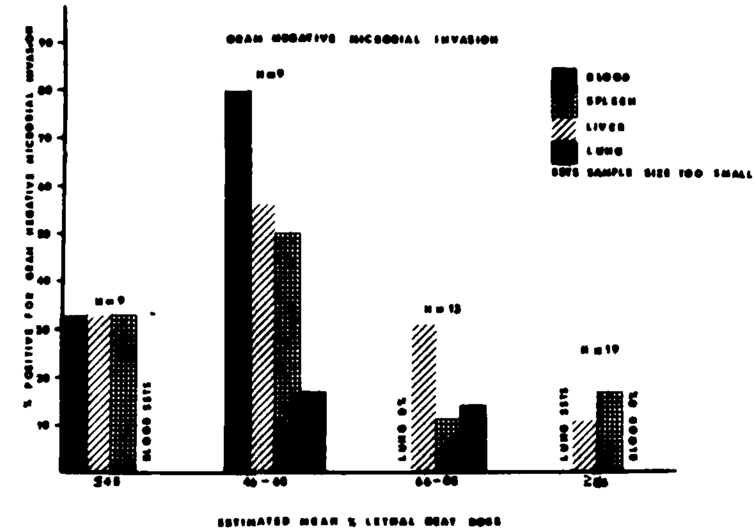

Figure 1. Percent positive for gram-negative microbial invasion of tissues and blood in non-surviving rats after heat stress.

The level of endotoxin invasion in non-surviving rats, as seen in Figure 2, was found in most cases to equal or be somewhat less than gram-negative microbial invasion. With the exception of the liver, the greatest percent of endotoxin invasion was found at an EM%LHD ranging between 45 and 65.

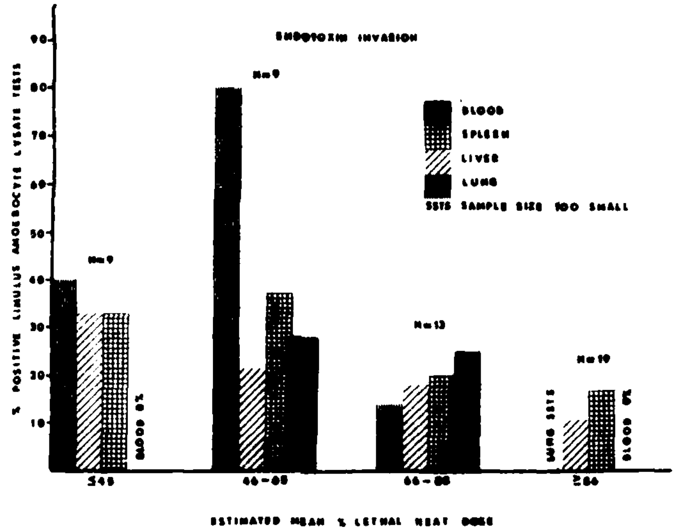

Figure 2. Percent positive Limulus Amoebocyte Lysate test found in tissues and blood in non-surviving rats after heat stress.

The decrease in the percent of samples with positive LAL tests as compared to the percent with gram-negative microbial invasion can be explained by the finding of a significant difference in the sensitivity of lysates to purified and non-purified endotoxins. It has been reported that though the sensitivity of lysates is quite good for a highly purified endotoxin, the sensitivity for endotoxin in its natural state is much less (6). Thus, endotoxin invasion as depicted in Figure 2 may actually be higher.

Figure 3 graphically illustrates the degree of gram-negative microbial and endotoxin invasion. This was accomplished by first determining the percent showing any sign of invasion. Rats were considered to have some sign of invasion if they had positive LAL tests and/or presence of isolates in either the blood, liver or spleen. Due to the lung control data, if rats only showed signs of invasion in the lung, this was not included as part of the invasion group.

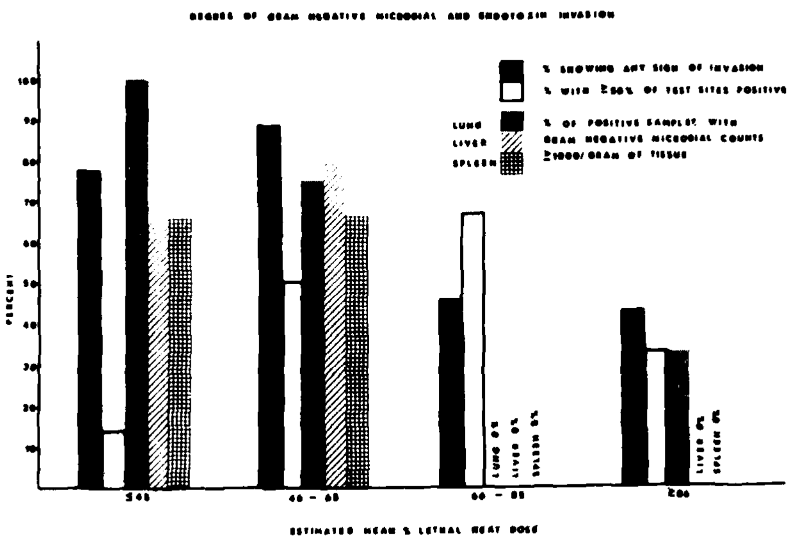

Figure 3. Degree of gram-negative microbial and endotoxin invasion in non-surviving rats after heat stress.

Next, an estimate of the degree of invasion was made by determining the percent of those with invasion which had at least half of the test sites positive for invasion. For example, if a rat had tests for invasion made on the liver, spleen, lung and blood then half of these tests would need to indicate invasion before it could be included in this group.

Finally, the degree of invasion was estimated by determining the percent of those with invasion which had gram-negative microbial counts greater than or equal to 1000/gram. This was considered to be a significant level of invasion for it is the smallest number of intact gram-negative microorganisms which can initiate a positive limulus test (7). Thus, it is an indication that the number of gram-negatives may be high enough for endotoxin to be playing some role in this invasion.

Though a few of these parameters are greater above and below an EM%LHD of 46 to 65, basically rats experiencing this level of heat stress appear to have the greatest degree of invasion. In this group, nearly 90% showed some sign of invasion. Half of these had at least 50% of the test sites positive for

invasion and the majority of tissue samples indicating the presence of gram-negative microbial invasion had counts greater than or equal to 1000/gram. As determined by the percent showing gram-negative microbial (Figure 1) and endotoxin (Figure 2) invasion, as well as by the degree of invasion (Figure 3), heat treatments resulting in an EM%LHD ranging between 46 and 65 had the strongest association between invasion and death due to heat stress.

Invasion of the liver by endotoxin and bacteria has been previously noted to occur in other forms of body stress (8). Associated with this invasion, a shift in the microflora of the small intestine has been noted (9). Table 2 shows a comparison of small intestine and cecum mean gram-negative microbial counts among control rats, and rats with and without invasion.

TABLE 2

Comparison of Small Intestine and Cecum Mean Gram-Negative Microbial Counts Among Control Rats, Rats with Invasion and Rats Without Invasion After Heat Stress

	SMALL INTESTINE SIGHTS			CECUM
INVASION	1	2	3	
+	4.19×10^{6} [a] (14/17)[c]	6.38×10^{7} [b]	2.95×10^{8}	1.96×10^{8} [a]
-	7.23×10^{4} (5/12)[c]	SST	SSTS	6.51×10^{7}
CONTROLS	(0/8)[c]	5.31×10^{2}	1.96×10^{6}	9.38×10^{6}

a = significantly greater than non invasion value

b = significantly greater than control value

c = ratio of the # of animals with gram-negative microbial counts $\geq$ 3000 per gram to TOTAL # tested

SSTS = sample size too small

Sections from three sites of the small intestine were examined: (1) 3-5 cm below the pylorous, (2) small intestine midpoint, and (3) 3-5 cm above the cecum. As shown in Table 2, small intestine site one had a dramatic shift in gram-negative microbial count increasing from 5.31×10^2 in the controls to 4.19×10^6 in rats with invasion. There was a significant difference between mean counts in the invasion and non-invasion groups but when control data was included, in an analysis of variance, no significant difference was apparent. If the data at site one is converted to frequency data by determining the ratio of number of rats with counts greater than or equal to 3000 per gram to total number in the group, then by chi square analysis, there is a significant difference among the ratios. At site two there was a significant difference between mean counts in the invasion group and control rats but no significant difference was found at site 3. Cecum data did not demonstrate as dramatic a shift in mean counts as small intestine site one, but there was a significant difference between invasion and non-invasion groups. It would appear that there is an association between elevated gram-negative microbial counts in certain areas of the small intestine and gram-negative microbial and/or endotoxin invasion of tissues and blood after heat stress.

These data tend to support the theory that in severe heat stress (EM%LHD greater than or equal to 86) the length of survival is not long enough to allow a significant change in the level of gram-negatives in the small intestine and thus the level of invasion is low. As heat stress is decreased, the length of survival increases, allowing time for changes in gut flora, resulting in invasion. This relationship holds apparently, until the level of heat damage is no longer sufficient to allow release of gut flora or cause impairment of the normal defense mechanisms which keep gut flora in check. As a result, the level of invasion begins to decrease below an EM%LHD of 45.

Work will continue to increase the N values of the different heat treatment groups in order to split these groups to reflect a smaller range of EM%LHD. Once the heat treatments which result in high levels of gram-negative microbial and/or endotoxin invasion have been specifically identified, the significance of this invasion on heat stress survival will be evaluated by examining survival rates between groups of endotoxin tolerant and non-tolerant rats.

Presentations:

DuBose, D. A., K. Basamania and J. Rowlands. Positive limulus amoebocyte lysate tests in plasma from healthy human subjects. Annual Meeting of the American Society for Microbiology, Los Angeles, Ca, 4-8 May 1979.

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(81024)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OC 6125	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
78 10 01	D. Change	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.01.A	3A161101A91C	00	024
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*

(U) Regulation of Body Weight (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012400 Personnel selection and maintenance (medical); 012900 Physiology; 003500 Clinical medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
77 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE

FISCAL YEAR		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
PRECEDING	79	.3	7.
CURRENT	80	.3	16.

19. RESPONSIBLE DOD ORGANIZATION

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TELEPHONE: 955-2831

SOCIAL SECURITY ACCOUNT NUMBER: [redacted]

PII Redacted

ASSOCIATE INVESTIGATORS

NAME: DANFORTH, E. (U of VT Med School)

NAME: LANDSBERG, L. (Harvard Med School) DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Fitness; (U)Body Weight Regulation; (U)Obesity; (U)Catecholamines; (U)Thermogenesis; (U)Thyroid

23. TECHNICAL OBJECTIVE.* 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) In collaboration with clinical research groups, assess the metabolic (USARIEM) and endocrine (clinical collaborators) responses of individuals with no body fat (lipo-adystrophy), limited body fat (anorexia nervosa and lipoatrophy), normal body fat but difficulties with weight regulation ("hard" and also "easy gainers") and excess body fat (obesity).

24. (U) Measure metabolic heat production and heat loss during exercise, pre- and post-prandial rest and basal conditions of such individuals on normal high and low caloric intake levels, with varied proportions of dietary carbohydrate, fat and protein, while simultaneously measuring their endocrine responses, with particular attention paid to thyroid regulation of body heat production and, consequently, body weight.

25. (U) 78 10 - 79 09 A collaborative study on "The effect of diet on thermogenesis in acquired lipodystrophy", a state marked by absence of functional body fat cells, has been completed and published. Intake of carbohydrate, fat, protein and total calories was varied; in contrast to the control subject, the lipodystrophic (LD) subject's resting metabolic rates (w/m^2) were elevated and varied directly with caloric intake, and were highest after 3d of protein supplement and lowest after a 3d fast. Serum T_3 levels of the LD subject, while in the normal range, also varied directly with the caloric content, were highest with protein and lowest after the fast, in contrast to the stable T_3 of the control subject. We conclude that lipodystrophy may demonstrate a form of dietary induced thermogenesis. A collaborative study on obesity, metabolism thyroid and catecholamine levels in PIMA Indians (diabetic and non-diabetic obese and lean groups) has been designed using the above variations; a specific investigation of their non-shivering thermogenesis is also planned.

*Available to contractors upon originator's approval

DD FORM 1498, 1 MAR 68 — PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element:	6.11.01A IN-HOUSE LABORATORY INDEPENDENT RESEARCH
Project:	3A161101A91C In-House Laboratory Independent Research
Work Unit:	024 Regulation of Body Weight
Study Title:	Regulation of Body Weight in an Obese and Diabetic Inbred Human Population, the Pima of Arizona
Investigators:	Ralph F. Goldman, Ph.D., Elliot Danforth, M.D., Orrin Tulp, M.D., Ethan Sims, M.D. (Univ of VT Medical Center) and Louis Landsberg, M.D. (Harvard Medical School)

Background:

Collaboration with clinical research groups studying endocrine regulation of body composition has been continuing over the past 10 years; they contribute expertise in thyroid, catecholamines and similar endocrine regulators, develop and staff the protocols through their own human use committees, obtain, house, feed and otherwise care for subjects and carry out all clinical and chemical assays; USARIEM staff obtains measurements of metabolism at rest or work at appropriate periods during the protocols and assess changes.

Progress:

Appropriate equipment has been specified, ordered and is being received. Methodology for body composition assessment by body water assay and underwater weight has been developed and technicians trained for these measurements at the Arizona study site. Other anthropometric measurements will include fat cell number and cell size at three sites as well as other elements in the Fogarty Conference specified data base for obesity.

Endocrine assays will include catecholamines (24 hour urine); creatinine, epinephrine and norepinephrine will be measured. Plasma evaluations of catecholamines will be taken in both the basal state and with upright posture; standing timed samples will be taken at 1, 2 and 5 minutes (orthostatic) and while squeezing a hand grip dynamometer at one-third maximum contraction for a five minute period (isometric) and these assessments will be interpreted for the general level of sympathetic tone. Exercise measurements using bloods (and/or

timed urines since 10 to 12 cc of blood per sample is required) will also be taken. It may be feasible to use tilt-table measurements for the assessment of orthostatic induction of alterations in circulating catecholamine levels.

Thyroid function will be assayed by measuring concentrations of T4, T3, RT3 and perhaps some of the T2's; the kinetics of all the foregoing will be carried out at baseline and following a period of weight reduction. However, there will be only two measurements of kinetics because each measurement involves 40 microcures of radiation and the Vermont Group's (these measurements will be the responsibiity of the Vermont Clinical Research Group) Human Use Committee has specified that total exposure will be less than 100 microcuries. With continued dieting, it is anticipated that RT3's will either remain flat or continue to fall with deprivation. It was decided that a basal measure of thyroid kinetics will be carried out in all 12 subjects; then the other of the two allowable measurements (40+40=80 microcuries) will be carried at various portions of the experimental protocol: some will be done at the end of starvation, some will be done midway into the refeeding recovery. TRH stimulation tests will be carried out at key times during the starvation, probably four times. Prolactin will be measured as a check on TRH stimulation tests since, if it is unchanged while TRH changes, then the change is not specific. Use of catecholamine blockers during starvation, to elicit mechanisms, was reviewed and discarded because of the already low activity during starvation. Testosterone, cortisols and free fatty acid assys may be also attempted in this initial study. Since alcoholism is a problem in this population, any subjects with high SGOT's will not be accepted from the tribe.

The overall caloric modification studies were discussed with a view to whether diet should be set at 25% of maintenance calories, or total starvation, to determine the net caloric efficiency during under nutrition as an adaptive mechanism; after having reduced the functioning fat cell mass over some 40 days, (on 500 kcal per day of a 40/40/20 caloric intake) weight loss in the Pima should approximate 13.6 ± 1.3 kg. Tentatively, it was decided that undernutrition would not be based on starvation, but on 25% of maintenance level; even this poses problems in comparing the obese Pima (non-and diabetic) and the lean Pima controls since the latter will have difficulty even at 25% of maintenance calories for a forty day period.

Metabolism (BMR, RMR pre and post breakfast and supper, and exercising metabolic rate at 3 speeds), activity patterns by pedometer and pre-meal activity history (3 hour recall, will be obtained, as well as PWC170); in addition, during the initial study of the first four of the 12 subjects, (three groups of 4 each) skin temperature at 3 sites and deep body temperature will be recorded during measurement of pre and post-prandial metabolism. USARIEM's involvement in this study will be primarily with the measurements specified in this paragraph.

A nearly complete paper on the metabolic and endocrine effects of smoking was reviewed and revised; a final draft will be forthcoming from Dr. Sims in the next month or so. Statistical analysis of the endocrine/metabolic correlations for the studies of overfeeding carbohydrate, fat and protein were reviewed, in preparation for the manuscript drafting to be done by Drs. Danforth and Horton at Vermont. The work on endocrine, metabolic and clinical responses of the naturally obese subjects to variation in their dietary regimens is being prepared for publication by Dr. Horton.

(81027)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
				DA OC 6127	79 04 30	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
78 10 01	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.01.A	3A161101A91C	00	027
b. CONTRIBUTING				
c. CONTRIBUTING				

11. TITLE (Precede with Security Classification Code)*

(U) Temperature and Sweat Production during Eccentric Work (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology; 016200 Stress Physiology; 005900 Environmental Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
77 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 78	1.1	19
	CURRENT 79	1.0	12

19. RESPONSIBLE DOD ORGANIZATION

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TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

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SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: KNUTTGEN, Howard G., Ph.D.

NAME: 955-2800 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Eccentric Work; (U)Negative Work; (U)Sweating Rate of Thermal Regulation

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Eccentric exercise is a situation where the muscle contracts to resist stretching or lengthening of the muscle as opposed to shortening of the muscle in concentric or positive exercise. Preliminary observations have indicated that sweat production is inordinately high during eccentric (negative) exercise as compared to standard concentric (positive) exercise. This high sweat rate appeared to diminish with eccentric training but returned to the high rate promptly after cessation of training. Temperature regulation during eccentric work has not been described. Core and skin temperature responses to eccentric work and their relation to these sweat rate observations have not been previously studied.

24. (U) The observations concerning high sweat rates will be confirmed on subjects performing eccentric exercise on a motor driven bicycle ergometer. Skin and core temperatures will be recorded and compared to standard concentric exercise. If eccentric exercise is found to ellicit a temperature regulating response different from concentric work, training will be evaluated as a modifier.

25. (U) 77 10 - 78 09 A bicycle ergometer suitable for eccentric exercise has been designed, fabricated and calibrated. Data collection will begin on 1 October 1978.

*Available to contractors upon originator's approval

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Program Element: 6.11.01.A IN-HOUSE LABORATORY INDEPENDENT RESEARCH

Project: 3A161101A91C In-House Laboratory Independent Research

Work Unit: 027 Temperature and Sweat Production During Eccentric Work

Study Title: Body Temperature Regulation Following Training With Eccentric Muscle Contractions

Investigators: Howard G. Knuttgen, Ph.D., John F. Patton, III, Ph.D., Kent B. Pandolf, Ph.D. and Ethan Nadel, Ph.D. (Yale Univ.)

Background:

Exercise with eccentric muscle contractions elicits a vastly different set of physiological responses in humans than does exercise with concentric contractions (1,2,4,7,9). For the same force development in repetitive rhythmic contractions, a markedly lower metabolic rate occurs as assessed by muscle metabolite levels, respiratory exchange, and accompanying ventilatory and circulatory events.

Exercise performed on a cycle ergometer with impressively high muscle force development can result in oxygen uptakes only 20-30% of the $\dot{V}O_2$max possible in similar exercise performed with concentric contractions. Additionally, persons not conditioned for such activity can experience a 50% increase in $\dot{V}O_2$ from the 10th min of exercise (e.g. from 1.0 to 1.5 l min^{-1}) before reporting an inability to continue (i.e., fatigue). Following a period of conditioning, the same exercise results in a lower $\dot{V}O_2$ (e.g. 1.0 l min^{-1}) throughout the exercise period and no difficulty in continuing for 1 h or more.

The physiological basis for this training phenomenon are not known. One of the hypotheses that has been advanced relates to the ways in which the active muscles deal with the combination of energy released by the metabolic events of the muscle cells and the energy received by the muscles as a result of the forced stretch involved in the eccentric contractions. The suggestion was advanced that, in the untrained state, the active muscles might develop such high temperatures that the elastic components were less able to contribute to the external force development necessary for exercise performance (3).

The purpose of the present study was to determine whether training with eccentric contractions led to a lower muscle temperature during such exercise which could result in the maintenance of the ability of the muscles to resist the application of the external forces of eccentric exercise. Additionally, the body's methods for regulating temperature under the conditions of eccentric contraction exercise would be compared to conventional leg cycling exercise.

Progress:

Six male subjects provided voluntary consent to participate in the study. Personal data pre-training (pre-T) are presented in Table 1. Following an initial period of instruction and practice, the subjects were given a pre-T test, 4-5 weeks of training with eccentric contractions, and a post-T test.

TABLE 1

Personal Data for the Subjects

Subject	Age,y	Ht,cm	Wt,kg	Concentric $\dot{V}O_2max$, $1\ min^{-1}$	Eccentric Exerc. Intensity,W
L	41	178.0	85.42	2.93	252
W	32	179.5	94.20	3.51	316
M	24	184.6	94.20	3.37	316
Y	26	181.2	98.74	3.85	316
S	23	174.2	79.93	2.92	252
B	28	176.5	75.01	3.03	275
	$\bar{X}$ =	179.0	87.92	3.27	
	SE =	$\pm$ 1.5	$\pm$3.80	+0.15	

The pre-T and post-T tests were identical for each subject. Exercise was performed at 60 rpm on a cycle ergometer, the pedal axle of which is driven in a reverse direction from normal cycling by an electric motor. The pedals thus are driven at the seated subject who resists the tendency of the ergometer to increase the pedal axle rpm from 60 to 66. The ergometer was so controlled that the subject had to provide a specific resistance power in order to maintain the 60 rpm. The range of exercise intensities employed was 252-316 W.

Pulmonary ventilation and respiratory exchange were determined by the Douglas bag collection technique and gas analysis for CO_2 (Beckman LB-2) and for O_2 (Applied Electrochemistry S3-A). Skin surface temperatures were recorded continually by type T copper-constantan thermocouples at eight points: forehead, upper arm, forearm dorsum of hand, back, chest, thigh, and calf. Muscle temperature (m. vastus lateralis) was determined with a needle thermistor immediately pre-exercise and during brief interruptions in exercise at 4, 15, 30, and when possible, at 45 and 60 min. Core temperature was determined continuously by esophageal thermistor. Body weight was recorded immediately pre- and post-exercise (Sauter K-120 electronic scale).

Venous blood samples (anticubital vein) were taken at rest and post-exercise after 1, 2, and 3 h for analysis of CPK as an indicator of muscle cell membrane damage. Rated perceived exertion (RPE) was determined for legs, upper body, and total body by use of the technique of Borg during exercise at 10, 25, and 40 min. Heart rate was determined by EKG.

Exercise intensities were assigned to each subject on the basis of aerobic power capacity ($\dot{V}O_2max$) while performing concentric exercise on the ergometer in the same body position and by general body proportions. In the pre-T test, the subjects were asked to exercise at 60 rpm as long as possible up to 60 min duration. For the post-T test, the subjects exercised for 45 min at the same intensities as pre-T.

Training with eccentric contraction exercise consisted of 12-15 sessions for each subject spread over a 5-week period and performed at exercise intensities equal to or in excess of those employed in the tests. Each session lasted for 60 min with the subject either exercising continuously or with short breaks in the activity as desired by each subject.

In the pre-T experiments, $\dot{V}O_2$ during the first 4 min of exercise ranged 0.75 - 1.30 l min^{-1} and then continued to demonstrate marked relative increases for the remainder of the exercise periods (Fig. 1). The averaged final values represented 133% of the 2-4 min values. Four of the subjects were unable to continue the exercise longer than 30 min. The $\dot{V}O_2$ at that time ranged 1.3 - 1.8 l min^{-1} (approximately 46% of $\dot{V}O_2max$) for these subjects with accompanying heart rates 118-163 beats min^{-1}. Two subjects were terminated at 45 min, one because of inability to continue. Subject W reported at 45 min the ability to continue indefinitely.

The 5-week training period resulted in a general decrease in $\dot{V}O_2$ for each phase of exercise (Fig. 1). For 3 subjects, little or no change from pre-T values was observed for the first 4 min of exercise while the remaining 3 experienced 0.2 - 0.7 l min^{-1} decreases. The $\dot{V}O_2$ was lower post-T compared to pre-T for all subjects during the remainder of exercise. For $\dot{V}O_2$ determinations 26-30 min, there was an average decrease of 0.55 l min^{-1} (range 0.30 - 0.80 l min^{-1}) as a result of training.

Body thermal response as measured by esophageal, skin, and muscle temperature are being assessed at present. A typical individual response of esophageal and mean weighted skin temperature is shown in Figure 2.

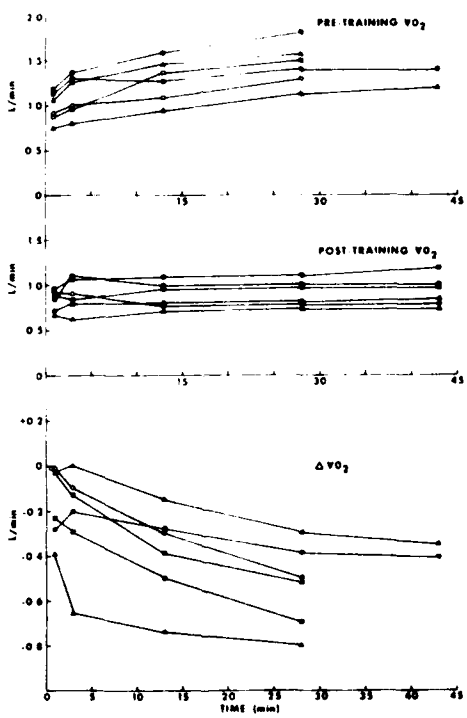

Figure 1. Individual responses in oxygen uptake (l/min) before and after training with eccentric muscular contractions.

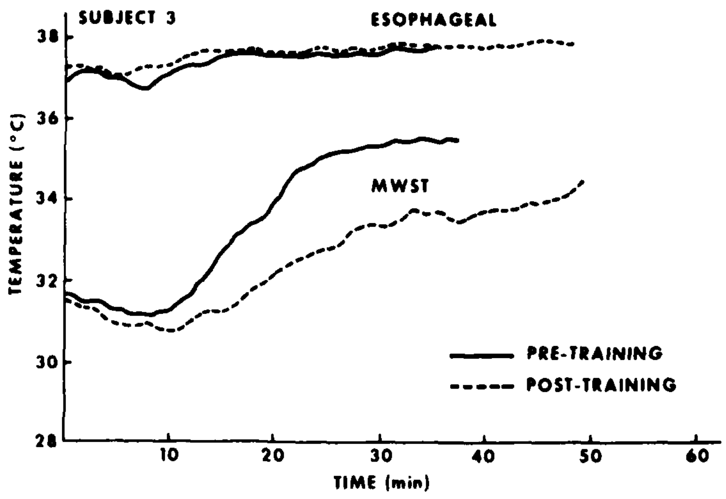

Figure 2. Typical response of esophageal and mean weighted skin temperature (MWST) to training with eccentric muscular contractions.

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(82001)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION		2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
				DA OA 6142		79 10 01	DD-DR&E(AR)636
3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	D. Change	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	001
b. CONTRIBUTING				
c. CONTRIBUTING	CARDS 114f			

11. TITLE (Precede with Security Classification Code) (U)Development and Characterization of Models of Cold Injury and Hypothermia (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS 002300 Biochemistry; 005900 Environmental Biology; 012900 Physiology; 003500 Clinical Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
70 07	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER: NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	4.6	88
	CURRENT 80	3	37

19. RESPONSIBLE DOD ORGANIZATION

NAME: USA RSCH INST OF ENV MED

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RESPONSIBLE INDIVIDUAL

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20. PERFORMING ORGANIZATION

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

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TELEPHONE: 955-2865

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: ROBERTS, Donald E., Ph.D.

NAME: 955-2863 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Cold Injury; (U)Frostbite; (U)Thermoregulation; (U)Osteocytes; (U)Cryobiology; (U)Fasciotomy

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Study factors involved in frostbite and other non-freezing injuries in both animals and man. Provide a rational basis for treatment and prevention of those injuries sustained by military operations.

24. (U) Attempts to produce radiographic bone changes seen in recuperation of frostbite victims will be included in an animal model. Hampster cheek pouch will be used to study the effect of compounds that inhibit platelet aggregation after freezing a portion of the pouch. The cheek pouch allows study of microvascular function through light microscopy and photomicroscopy.

25. (U) 78 10 - 79 09 The fasciotomy and vasodilator paper demonstrating prolongation of vascular integrity and increased tissue salvage is accepted for publication. Radiometry for blood flow proved to be too cumbersome and had numerous engineering problems. No further work with radiometry is projected at this time. Finger cooling in air data is progressing and analysis continues. Radiographic lytic lesions, which are similar to those produced in man from mild frostbite, have been reproduced in an animal model.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 001 The Development and Characterization of Models of Cold Injury and Hypothermia

Study Title: An Evaluation of Various Methods of Rewarming Hypothermic Victims

Investigators: Donald E. Roberts, Ph.D. and John Patton, Ph.D.

Background:

Accidental hypothermia continues to be a problem encountered by mountain rescue teams, ski patrols and emergency treatment facilities despite the increased public awareness of the dangers of exposure to chilling environments. Soldiers in combat or field training situations are particularly susceptible to hypothermia due to prolonged exposure to harsh environments, isolation and a high risk of traumatic injury. Effective treatment of hypothermia is accomplished by either external rewarming methods or by internal rewarming methods, often referred to as core rewarming. Recent investigations have shown core rewarming to be superior to external methods because of a more rapid return to normal body temperature and a decrease in the incidence of complications often experienced during external rewarming such as an after-drop in core temperature, "rewarming shock," arrhythmias, and ventricular fibrillation. The most common core rewarming techniques are peritoneal dialysis and the establishment of an arteriovenous shunt through an external heat exchanger. While effective, these procedures have limited applicability because of the requirement for a well staffed and equipped medical facility. A more recent development in core rewarming techniques is rewarming by ventilation with warm, humidifed air or oxygen. Since this technique is non-invasive and can be performed in the field, it has attracted a lot of attention from paramedics as well as civilian and military emergency treatment facilities. Unfortunately, there is a notable lack of good data on the effectiveness or even the safety of inhalation therapy for treatment of hypothermia.

It would be appropriate therefore, to undertake a comparison of the various rewarming techniques in order to define their relative merits and disadvantages

in physiological terms. To date, there has not been any study which has evaluated external, peritoneal dialysis, arteriovenous shunt and airway rewarming procedures on the same animal preparation. Such an evaluation would be a valuable addition to the existing literature on treatment of hypothermia. It would also enable military medical specialists to evaluate the various rewarming procedures in terms of the special considerations and capabilities of military emergency medical treatment facilities.

External Rewarming Methods

External rewarming of a hypothermia victim may be accomplished by active or passive means. Active rewarming refers to heating the surface of the victim with warm water, heated blankets, or any other means where there is a substantial transfer of heat from the environment to the victim. The rate of heat transfer is determined by the temperature difference between the victim and the external medium as well as the thermal conductivity of the victim and the medium. By these criteria, immersion in water heated to 35 to 45°C is the most practical method of active external rewarming. The time to rewarm a victim depends on a number of factors, the major one being the initial body temperature of the victim. Compared to core rewarming techniques, external rewarming is relatively slow often requiring four or more hours (6).

The major problem of rewarming hypothermic individuals by external techniques is that the skin and peripheral tissues are warmed before the central organs and tissues. During hypothermia cardiac function is depressed but so are circulatory requirements due to profound peripheral vasoconstriction and reduced metabolism. When rewarming is initiated by external means there is a vasodilation of peripheral blood vessels due to the direct action of heat upon the tissues. This sudden expansion of the vascular system reduces central blood volume and cardiac output, events which often lead to circulatory collapse (2). In the initial stages of external rewarming blood returning to the heart from the periphery will be colder than the heart and there is often an even further decrease in central body temperature. Since it has been shown that the danger of asystole or ventricular fibrillation is greatest when core temperature is in the range of 25 to 28°C (1), any further decrease in core temperature which would bring the heart closer to this critical zone should be avoided. The importance of minimizing or eliminating this "after-drop" in core temperature is evident when one considers that most deaths during hypothermia are due to asystole or ventricular fibrillation (5).

The extent of peripheral vasodilation and presumably its adverse effects can be reduced during external rewarming by simply excluding the neck, head, arms and legs from the rewarming medium. Although there is not data comparing whole body versus trunk only external rewarming, physiological considerations dictate a "trunk only" approach whenever external rewarming is used.

Passive external rewarming consists of simply wrapping the victim in some insulating material thereby trapping his own metabolic heat. Since metabolism and thus heat production decrease with decreasing body temperature, rewarming by this means is extremely slow. Since both depth and duration of hypothermia are determinants of the success or failure or rewarming (4), passive external rewarming has little to recommend it except that it may be the only means available in a survival situation.

In summary, although external rewarming methods are widely used mainly because of their simplicity, they are associated with relatively high mortality. The main problems are shown rewarming time, peripheral vasodilation leading to rewarming shock, and an after-drop in core temperature. Internal or core rewarming techniques reduce or eliminate these problems. Various core rewarming techniques are discussed below.

Core Rewarming Methods

Peritoneal Dialysis

Recent reports from this laboratory have demonstrated the benefits of peritoneal dialysis relative to external rewarming of hypothermic dogs (12, 13). Compared to the external method; rewarming by peritoneal dialysis reduced rewarming time, minimized increases in peripheral blood flow, and resulted in an improvement in cardiac and renal performance both during and after rewarming. Although the rate of rewarming with peritoneal dialysis is greater than that with external methods, the difference is not dramatic. To achieve significantly faster rewarming times and retain the advantages of core rewarming, a more efficient means of heat transfer such as extracorporeal heat exchange via an arteriovenous shunt has been used.

Arteriovenous Shunt Rewarming

A-V shunt rewarming has been used clinically as a treatment of hypothermia. In the most usual case, blood is pumped mechanically through a heat exchanger and then an oxygenator before being returned to the body. Large

amounts of heat can be transferred in this manner and rewarming times are decreased from the 4 or more hours required by the external techniques to only 1 or 2 hours (9). The major objection to the use of A-V shunt rewarming for the treatment of accidental hypothermia is the requirement for large and expensive pump oxygenators and highly trained medical personnel. Gregory et al. (7) have reported a simpler A-V shunt rewarming technique which does not use a blood pump or an oxygenator.

While there is much physiological evidence to recommend peritoneal dialysis and A-V shunt rewarming methods, most accidental hypothermia victims are still rewarmed by external methods. As mentioned previously, the reasons are the level of medical expertise required, the expense and availability of equipment, and the additional risks of surgery associated with the core rewarming techniques. Because of these considerations, there has been much attention given to the relatively new technique of core rewarming by ventilation with warm gas.

Airway Rewarming

Inhalation rewarming is an attractive concept since it utilizes a highly efficient heat exchanger through which nearly the entire cardiac output passes. In addition, the warmed blood passes directly to the heart thus minimizing heat loss to peripheral tissues. Actual cases where inhalation rewarming has been used to rewarm hypothermic humans have demonstrated that: 1. rewarming can be accomplished, 2. the after-drop in core temperature following initiation of rewarming can be eliminated or at least minimized, 3. there is immediate and continued improvement in pulse rate and blood pressure (8,10).

The major drawback of using inhalation rewarming to treat hypothermia is that the time required for complete rewarming is approximately the same as that achieved by using external methods alone (3,8,10,11). The reason for this is the relatively low heat capacity of air or oxygen. The amount of heat transferred by this technique is increased considerably if the inspired air is humidified. This is due to the latent heat transferred to the respiratory tract surfaces when water vapor condenses. In fact, if a careful analysis of the inspired and expired air temperatures and water vapor contents were available on the case histories of inhalation rewarming, it would probably show that most of the heat transferred was due to condensation of water vapor and that only 10 to 20% of the total heat transferred was due to convective heat transfer by the

gas. Nevertheless, the rate of heat exchanged by ventilation with warm humidified gas is still only a small fraction of what can be achieved by other internal rewarming techniques.

The fact that the inspired gas is usually humidified at a temperatue greater than the body temperature of the hypothermia victim brings up a point which has not received due consideration in the literature on inhalation rewarming. The condensation of water vapor in the respiratory tract can lead to significant accumulation of water in the lungs. Whether or not this will represent a serious complication during rewarming depends on the following factors: the temperature and water vapor gradients employed; the length of the rewarming procedure; the position of the victim; and the ability of lung tissue to keep the pulmonary exchange surfaces "dry". While the first three factors can be controlled, the fourth factor has not been properly assessed. The magnitude of the respiratory water load that can be tolerated during hypothermia awaits future physiological investigations.

Progress:

In this study we will be comparing active external rewarming (heated blanket) and active external with active airway superimposed. This is to counter the effects of the passive external rewarming that would occur if only airway rewarming is used.

Parameters being measured include: EKG, cardiac output (dye dilution), arterial pressure, right heart temp, rectal temp, esophageal temp, and mean weighted skin temp (4 pts). Dogs are cooled to 27^{o}C and rewarming is then started. All parameters are recorded and will be compared at a later date.

Several dogs have been cooled and all equipment problems have been solved. Data collection is awaiting the arrival of research animals for this study.

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Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	001 The Development and Characterization of Models of Cold Injury and Hypothermia
Study Title:	Effects of Dehydration on Peripheral Cold Response
Investigators:	Joel J. Berberich, CPT, MSC, Ph.D. and Donald E. Roberts, Ph.D.

Background:

The state of hydration has a definite effect on both central and peripheral heat transfer rates in a warm environment, even in a resting subject (1). Dehydration causes an increase in heating rate, in part due to a reduction in peripheral blood flow. Although dehydration should logically also have a pronounced effect on peripheral cooling rate, due in part to blood redistribution, altered osmolality and increased hematocrit, this effect has never been investigated. Since soldiers routinely may dehydrate in cold environment in the field, it is important to ascertain whether this dehydration adversely affects hand cooling and cold injury susceptibility. It might be predicted that mild exercise would potentiate the effects of dehydration in the cold. This prediction is based on the premise that increased cardiac and muscle blood flow shunted by exercise would further reduce blood flow to non-exercised extremities (2).

Progress:

To evaluate the effects of dehydration on response to peripheral cooling, a two phase study was conducted: resting men (Phase I) and exercising men (Phase II).

During Phase I, the effects of dehydration were evaluated by studying individual's responses to a prolonged cooling test in cold air before dehydration, after dehydration, and following rehydration. Two groups of twelve subjects were studied in Phase I. One group was dehydrated to 5% body weight loss by mild exercise and restricted fluid intake, the other group (controls) underwent the same experimental procedures but maintained their fluid balance by drinking water *ad libitum*.

During Phase II the same design was followed except that while undergoing the prolonged air cooling test subjects also exercised at a low level. The rationale of Phase II was to evaluate the effect of moderate physiological demand in addition to dehydration on the subjects, as this is a more usual military situation.

The subjects were dehydrated by restricted fluid intake and mild exercise over a period of three days. Dehydration was monitored by body weight changes and by daily blood and urine chemistry profiles.

The cold test consisted of sitting in a chamber at $0^{\circ}C$ for 135 minutes dressed comfortably in military cold weather clothing. For the last two hours of this test, one bare hand was exposed to the cold air to assess hand cooling. During this test, 16 skin temperatures, rectal temperature and heart rate were continuously measured. Blood pressures and oxygen consumption were measured at intervals. During Phase II of the study, the test subjects exercised on a bicycle ergometer for interrupted periods at low exercise levels.

The data for Phase I have been analyzed and a manuscript is being readied for submission.

Data from ten subjects in each group was compared. In the dehydrated group, the average drop in body weight was 4.6%. All blood and urine measures indicated dehydration and within 20 hours of rehydration, their weight was within 0.3% of initial weight.

The data on the exposed hand shows a significant decrease in hand temperature in the dehydrated subjects as compared to the normally hydrated subjects. We concluded that dehydration under laboratory conditions does have a determinal effect on the response of a person to cold. Field documentation of these findings are necessary, but we feel that every effort should be expended to provide adequate fluid to soldiers under field conditions to counteract these effects.

Presentations:

Roberts, D. E., J. J. Berberich and R. E. Droege. The effects of dehydration on peripheral cooling. Federation of American Societies for Experimental Biology, Dallas, TX, 1-10 April 1979. Fed. Proc. 38:1055, 1979.

LITERATURE CITED

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(82002)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OA 6144	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
78 10 01	D. Change	U	U	NA	NC	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	002
b. CONTRIBUTING				
c. XXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)* (U)Development and Characterization of Models to Study Acute Mountain Sickness and High Altitude Pulmonary Edema in Military Operations(22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology; 005900 Environmental Biology; 012600 Pharmacology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
70 07	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	6	188
	CURRENT 80	7	128

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

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20. PERFORMING ORGANIZATION

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* CYMERMAN, Allen, Ph.D.

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SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: YOUNG, Andrew J., Ph.D., CPT, MSC

NAME: MAHER, JOHN T., Ph.D., DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Acute Mountain Sickness; (U)Ventilatory Acclimatization; (U)Body Fluid Shifts; (U) ^3H; (U) $^{35}SO_4$; (U)Spontaneous Motor Activity

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Acute mountain sickness and high altitude pulmonary edema are debilitating disorders associated with the lowered oxygen present at high terrestrial elevations. Many of the physiological and biochemical parameters of these disorders cannot be studied in man due to the invasive nature of the measurements. The purpose of this work unit is to develop appropriate animal models to enable: (1) the elucidation of the physiological and biochemical adaptations which occur in response to the stress of high terrestrial elevations; and (2) the identification of new approaches for improving military effectiveness at high terrestrial elevations.

24. (U) Models will be developed and/or used for investigating: (1) physiological and biochemical responses to altitude; (2) control mechanisms operative in these responses; (3) etiology and symptomatology of acute mountain sickness and high altitude pulmonary edema and; (4) related functional deficits and disabilities.

25. (U) 78 10 - 79 09 (1) A plethysmograph has been developed for measuring pulmonary ventilation in unrestrained and unanesthetized rodents. The ability to make such measurements is important to the development of new animal models for studying ventilatory acclimatization to high altitude and the effects of drugs on pulmonary ventilation in the presence of chronic hypoxia; (2) Using the rat as the model system, altitude-induced shifts of fluid into various organs, including brain and lung, have been observed within a time frame similar to that of altitude sickness in man. Excessive variability within the measurements prevented quantification of these fluid shifts using ^3H_2O and $^{35}SO_4$; other methods must be explored; (3) An automated system to quantify spontaneous motor activity in the rat has been developed for investigating the relationship between hypoxia and the depression of spontaneous motor activity.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 002 Development and Characterization of Models to Study Acute Mountain Sickness and High Altitude Pulmonary Edema in Military Operations

Study Title: Development of a Plethysmograph for Measuring Pulmonary Ventilation in Unrestrained Rodents

Investigators: Ronald A. Gabel, M.D., Vladimir Fencl, M.D., David E. Leith, M.D. and Vincent A. Forte, Jr.

Background:

Measurement of pulmonary ventilation in unrestrained and unanesthetized animals is important to the development of new animal models for studying (a) ventilatory acclimatization to high altitude and (b) the effects of drugs on pulmonary ventilation in the presence of chronic hypoxia.

A particularly attractive method for measuring the tidal volume and frequency of breathing in small animals confined to a closed box is the barometric method of Drorbaugh and Fenn (1). This technique depends upon the pressure change in a tight box that results when an animal inspires air that is saturated with water at the temperature of the box. When taken into the lungs, the air is not only warmed to body temperature but is also further humidified to saturation at its new temperature. The combination of warming and humidification produces an increase in box pressure during inspiration, which returns to the starting pressure as the gas is exhaled.

The Drorbaugh-Fenn method has been successfully applied by others to measure the pulmonary ventilation of small animals (2,3,4). It has recently been used to show that rats can be used as a model for humanlike ventilatory acclimatization to high altitude (5).

Progress:

A plethysmograph box has been fabricated, and we have begun testing its frequency response. Early assessment, using new technology recently developed

at Harvard School of Public Health (Andrew C. Jackson, Ph.D., Unpublished Observations) indicated that amplitude of the output for a given input was not constant throughout the range of frequencies that may be encountered when measuring the pulmonary ventilation of small animals. Therefore, we are now developing the facility to measure the frequency response of such devices, using the method of A. C. Jackson. This will permit us to change the design of our plethysmograph empirically so that it will have a "flat frequency response" in the range of frequencies expected to be encountered when using the device.

For testing frequency response, a speaker box with pressure transducers has been manufactured, and fabrication of a power supply for the transducers is in progress. Dr. Jackson has modified his computer program for controlling the system so we can utilize the PDP-1103 at USARIEM to implement our application of the technique.

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Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	002 Development and Characterization of Models to Study Acute Mountain Sickness and High Altitude Pulmonary Edema in Military Operations
Study Title:	Effect of Altitude on the Body Fluid Spaces and Behavior of the Rat
Investigators:	Allen Cymerman, Ph.D. and Andrew J. Young, CPT, MSC, Ph.D.

Background:

During the first few days of exposure to altitude (above 2500 m) unacclimatized subjects manifest a variety of symptoms collectively known as acute mountain sickness (AMS). This syndrome is characterized by headache, anorexia, vomiting, lassitude, dizziness, irritability, impaired judgment, and inability to concentrate. The occurrence of AMS during Army operations at altitude can have detrimental effects on both physial and mental performance. Although AMS is well described, its etiology remains unknown. The use of an animal model for the basic study of AMS would allow study of the pathophysiolgy of the disorder as well as pharmacological intervention aimed at decreasing symptom severity.

Progress:

Work on this project has developed along two avenues. The first involves measurement of altitude-induced changes in body fluid compartments of the rat. Our early investigations in this area were prompted by results of the changes in wet-dry weight ratios of several rat organs with exposure to altitude. We demonstrated increases in hematocrit, hemoglobin, and the water content of several organs within 1-2 days of exposure to 5486 m simulated altitude. In addition, we showed that the organs examined differed in the amount of fluid gained, with brain and lung showing the greatest increase. Our current work is

an attempt to quantify the fluid shifts by determining intra- and extracellular fluid compartment volumes. This could not be accomplished using the wet-dry weight technique.

Using two radioisotopes, $^{35}SO_4$ and ^{3}H, injected intraperitoneally and allowed to equilibrate, it was hoped that estimates of the volume of the intra- and extracellular compartments could be obtained. The technique of radioactive injections and sample collections, as well as data analysis were developed. Standardization experiments and preliminary studies were conducted at sea level and simulated altitude (4572 m). The results were not encouraging. Methodological problems, including measurement variability, prevented conclusions concerning changes in fluid spaces. In vitro experiments showed a 9% overestimation of compartment volumes, a change of approximately the same magnitude expected in the in vivo experiments. Furthermore, our calculations indicated that sufficient radioactivity was lost via the urine, especially at altitude, to completely invalidate the measurements. In an attempt to correct this problem, a device was designed to collect voided urine, but restraint of the rat was necessary. This posed a problem during long experiments. After consideration of the technical problems, we have discontinued further studies using radioactive tracers and have returned to the use of the wet-dry weight ratios to investigate organ fluid volumes.

The second avenue of endeavor involves the quantification of behavioral changes which occur in the rat during acute altitude exposure. Experiments are in progress to explore the relationship between the degree of hypoxia and the extent of spontaneous motor activity depression in rats. It is hypothesized that changes in motor activity will resemble manifestations of AMS in man.

A software program has been written for the PDP-1140 computer to analyze data from eight activity monitors, but problems of physical interfacing have not been solved. The substitution of a portable MINC computer system is now in progress. This system has been tested under hypobaric conditions and found to be fully operational. This allows an on-line dedicated data analysis capability in the hypobaric chamber.

Studies will continue in an attempt to: 1) establish changes in rat behavior with different altitudes and exposure durations and 2) study wet-dry organ weight changes with drug intervention.

(82005)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
				DA OC 6145	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	D. Change	U	U	NA	NL	X YES ☐ NO	A. WORK UNIT

10. NO. CODES*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	005
b. CONTRIBUTING				
c. ~~CONTRIBUTING~~	CARDS 114f			

11. TITLE (Precede with Security Classification Code)*

(U) Models of Heat Disabilities: Preventive Measures (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

016200 Stress Physiology; 005900 Environmental Biology; 003500 Clinical Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER*: NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	7.4	280
	CURRENT 80	9	314

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

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TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* MAGER, Milton, Ph.D.

TELEPHONE: 955-2871

SOCIAL SECURITY ACCOUNT NUMBER

ASSOCIATE INVESTIGATORS

NAME: HUBBARD, Roger, Ph.D.

NAME: FRANCESCONI, Ralph P., Dr.

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Heat Stress; (U)Heat Disabilities; (U)Body Temperature; (U)Tolerance; (U)Heat

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The use of model systems to study the effectiveness of various measures designed to prevent, forestall or reduce the disabilities, injuries or performance decrements associated with military operations in the heat.

24. (U) A variety of suggested preventive measures e.g. prehydration, dietary supplementation and pharmacological agents will be evaluated in animal models for their effectiveness in forestalling or protecting from heat injury.

25. (U) 78 10 - 79 In a human study we investigated sexual differences in performance of and physiological responses to equal exercise in dry heat. Initially, active women performed as well as active men, moreover the women acclimatized to exercise in dry heat at a faster rate or to a greater extent than did the men. In other experiments rats were administered agents which resulted in hypothermic responses lowering Tre to 30°C. When these hypothermic animals were subsequently exercised in the heat (35°C), their endurance capacities were increased by as much as 50% when compared to control animals. However, this preinduced hypothermia had no effects on either survival or recovery rates and the pathochemical indices of heat/exercise induced injury were also unaffected. Since the degree to which an artificial heat acclimatization process can prevent or forestall serious heat disorders has never been objectively measured, we have exposed 54 experimental rats to five, short, daily bouts of hyperthermia (T core 40.4°C). When subsequently reexposed to high ambient temperature, the acclimatized rats had: 1) a lower heating rate, 2) a lower hematocrit despite greater weight loss and 3) a lower mortality rate (24%) compared to controls (69%) despite a longer exposure time (84 vs 55 min). The data suggest that short daily bouts of sub-lethal hyperthermia can produce an increased resistance to subsequent lethal heat exposures.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness, and Medical Factors in Military Performance

Work Unit: 005 Models of Heat Disabilities: Preventive Measures

Study Title: Heat Injury: Studies on Mechanisms, Prevention, and Predisposition

Investigators: Ralph P. Francesconi, Ph.D. and Milton Mager, Ph.D.

Background:

A variety of physiological factors have been identified which may be helpful in preventing heat injury when individuals must work under extreme heat conditions. For example, heat acclimatization, proper hydration levels, adequate physical fitness, abstention from the use of alcohol and other drugs, and other factors may permit individuals to work in the heat with reduced possibility of heat disability. Alternatively, relatively few recent studies have been concerned with identifying pharmacologic agents which may be useful in reducing the physiological cost of work in the heat. We hypothesized that pharmacological intervention which results in whole-body hypothermia may produce beneficial effects when administered prior to an exhaustive run in a hot environment.

Many studies have been reported which demonstrate hypothermic effects on sedentary animals of a variety of compounds including amino acids (1), monoamines (2), metabolic inhibitors (3), calcium (4) and narcotics (5). However, to the best of our knowledge our forthcoming paper (6) is the only report which addresses the possibility that previously hypothermic animals may be able to work in the heat with reduced physiological cost. In this paper we demonstrated that hypothermia previously induced in rats by cold exposure in combination with L-tryptophan or chlorpromazine administration, increased the endurance capacity of these animals to work in the heat although few additional thermoregulatory or clinical chemical benefits were observed.

In order to extend these studies and to test the efficacy of 5-thio-D-glucose (5-TG), an analogue of glucose which we recently demonstrated is very effective in producing hypothermia (7), we investigated the effects of hypothermia induced in rats by 5-TG on the ability to exercise in the heat. Additionally, because amphetamine has been shown to be an effective agent for

inducing hypothermia (8) as well as increasing physical performance (9), we wished to study also the effects of hypothermia induced by amphetamine pretreatment on the ability to exercise in the heat.

Progress:

Accordingly, we catheterized (external jugular vein) adult, male Sprague-Dawley rats (250-340 g) for administration of low doses of either 5-TG or D-amphetamine as well as blood collection. After drug administration the animals were placed under restraint in a cold room ($4^{o}C$) until Tre of 30^{o}-$31^{o}C$ were attained. The animals were then removed to a heated chamber ($35^{o}C$) where they exercised on a treadmill to hyperthermic exhaustion (Tre $\approx 42.5^{o}$ - $43^{o}C$). Tre and Tsk were continuously monitored, and small volumes (1 ml) of blood were removed at appropriate times prior to and after completion of the run.

Thermoregulatory responses of animals treated intravenously with 10 mg of 5-TG are depicted in the first two figures. Since thermoregulatory characteristics between a group of normothermic, fed controls (n=7) and normothermic, food-deprived (18 h) controls (n=6) were not significantly different, the results were combined for statistical purposes. From Figure 1 it can be observed that control rats remained on the treadmill for approximately 33 min whereas for 5-TG hypothermic rats the endurance capacity was increased significantly ($p < .001$) to 49 min. In Figure 2 it can be readily observed that, despite the fact that both groups of animals were previously exposed to cold ($4^{o}C$) to induce hypothermia in the 5-TG treated rats, after approximately 15 min on the treadmill Tsk began to diverge, and control animals displayed higher Tsk from 15-40 min.

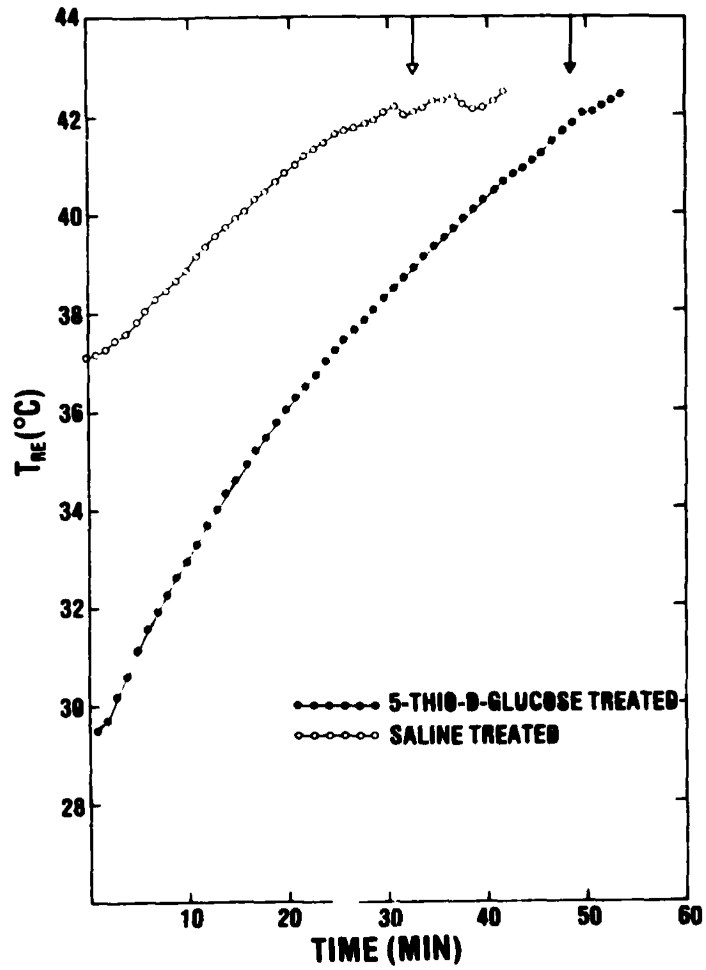

Figure 1. Effects of pretreatment with 5-TG on the Tre response to exercise in the heat. Whereas control rats had initial Tre of approximately 37.2°C, 5-TG treated animals began the run in the heat with Tre averaging 29.7°C. The arrows deonote the average time on the treadmill at which hyperthermic exhaustion occurred in the two groups.

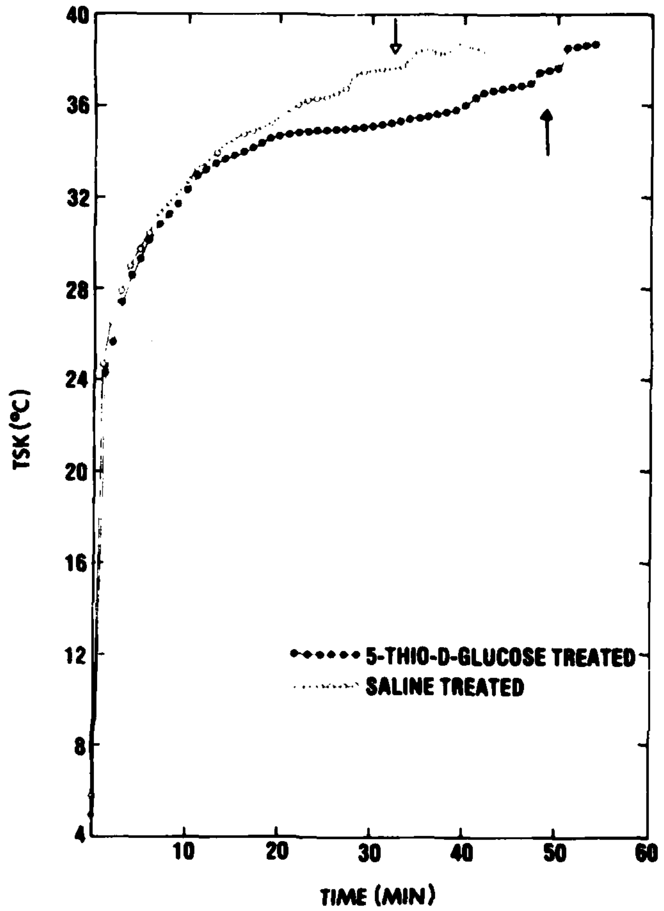

Figure 2. Tsk response to exercise in the heat of animals which had been pretreated with 5-TG or control animals pretreated with physiological saline. Average treadmill run time to hyperthermic exhaustion for the two groups of rats are denoted by the arrows.

From Table 1, however, it is clear that maximal Tsk for the two groups was not statistically different. It is interesting to note from these data that because of the initially reduced Tre among 5-TG treated animals Tre max is significantly

reduced. It is likewise significant to observe that despite increased time on the treadmill (48.83 min) for 5-TG treated animals, their increase in Tre per unit time (.253°C/min) was significantly greater than for control rats (.171°C/min) while the reverse is true for increments in Tsk. This indicates that despite the exercise in a hot environment, disturbances in homeothermic regulation (initially greatly reduced Tre) override the drive to lose heat peripherally irrespective of the exercise and ambient conditions forced upon the animals.

TABLE 1
SUMMARY OF THE RESULTS DEMONSTRATED IN FIGS. 1 AND 2

	TIME ON TREADMILL (MINUTES)	RECTAL TEMPERATURE MAXIMUM (°C)	ΔT_{re}/MIN ON TREADMILL (°C)	SKIN TEMPERATURE MAXIMUM (°C)	ΔT_{sk}/MIN ON TREADMILL (°C)
CONTROL NORMOTHERMIC					
$\bar{x}$	32.92	42.61	.171	37.41	.984
$SE_{\bar{x}}$	1.65	.09	.007	.43	.043
5-THIO-D-GLUCOSE HYPOTHERMIC					
$\bar{x}$	48.83	41.72	.253	37.06	.659
$SE_{\bar{x}}$	1.19	.28	.005	.34	.010
t	6.14	3.905	7.675	.514	5.012
p	< .001	< .005	< .001	NS	< .001

Figures 3-6 demonstrate the effects of 5-TG induced hypothermia (pre-run blood samples) and exercise to hyperthermic exhaustion (post-run blood samples) on plasma glucose levels as well as several clinical chemical indices of heat injury. Figure 3 demonstrates the intense hyperglycemia ($p < .001$) which occurs after 5-TG administration even in rats which had been food-deprived for 18 h (n=6). While the exercise to hyperthermic exhaustion did not have marked effects on the glucose concentration of fed, control rats, plasma glucose was significantly reduced in the 5-TG treated, food deprived ($p < .001$) animals.

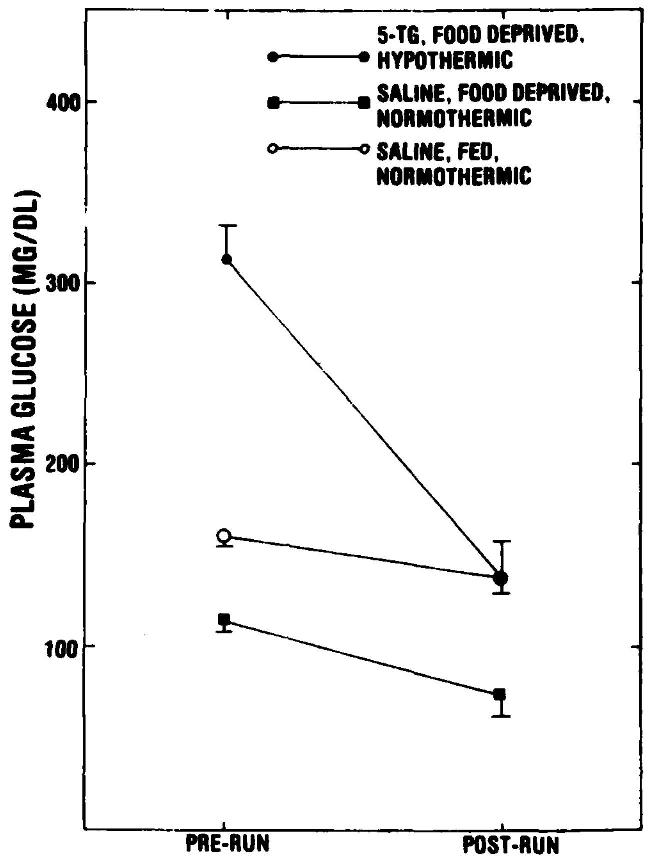

Figure 3. Effects of 5-TG administration and food deprivation on plasma glucose levels prior to and immediately following exercise to hyperthermic exhaustion in a hot environment. Mean values $\pm$ SEM for at least 6 animals/group are shown.

We had previously demonstrated (10) that following exercise to hyperthermic exhaustion circulating levels of lactate and potassium (K^+) may be useful indices of the extent of heat injury. Figure 4 demonstrates the effects of 5-TG induced hypothermia on the plasma levels of lactate immediately prior to and following exercise to hyperthermic exhaustion. While lactate levels are significantly increased in both food-deprived and fed rats ($p < .001$), it is clear

that in the 5-TG treated animals levels of lactate are even higher than both of these ($p < .001$). This, of course, is commensurate with the longer run time for the 5-TG treated rats. In Figure 5 analogous results are noted for plasma creatine phosphokinase (CPK) levels. It should be explained that levels of CPK are less consistent from animal to animal, and the huge increase in CPK in the 5-TG treated rats represents increase of up to 1500 units in one animal and as few as 100 units in another. Again, however, the increased endurance capacity in the 5-TG hypothermic rats is reflected in the steep increase in CPK levels in these animals. In Figure 6 again it is clear that the greatest increments in K^+ levels occured in the longest-running (5-TG) animals.

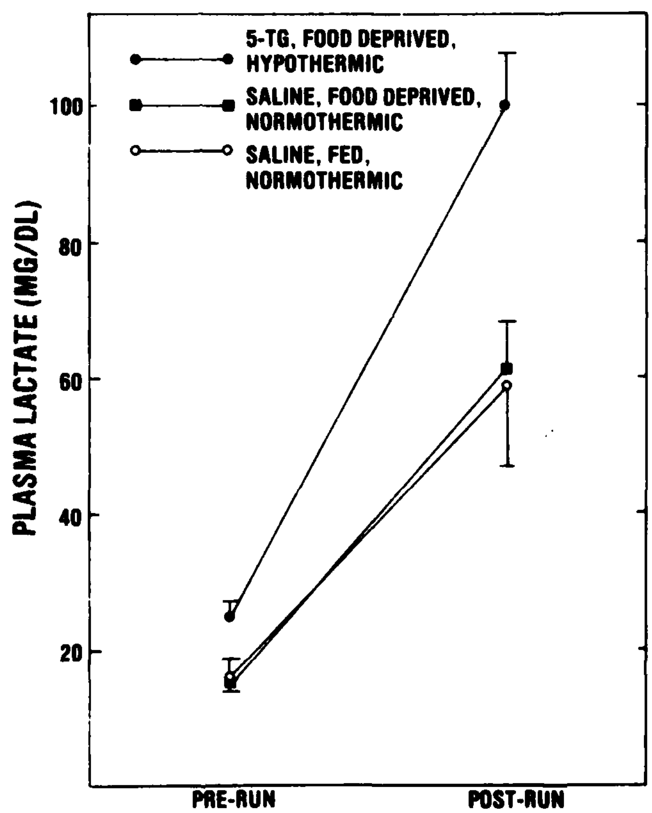

Figure 4. Effects of 5-TG administration and food deprivation on plasma lactate levels prior to and immediately following exercise to hyperthermic exhaustion in a hot environment.

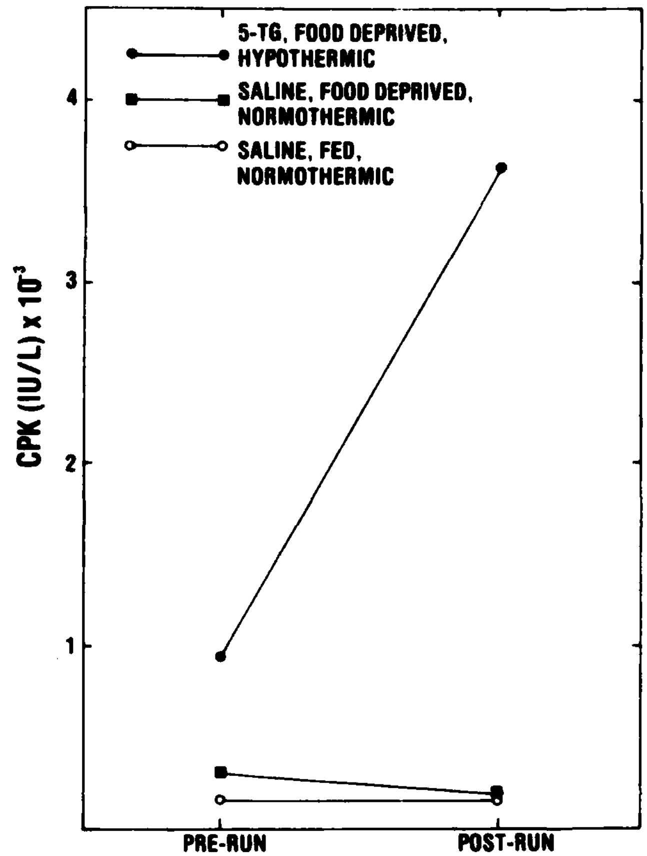

Figure 5. Effects of 5-TG administration and food deprivation on plasma creatine phosphokinase levels in plasma immediately prior to and subsequent to exercise to hyperthermic exhaustion in a hot environment.

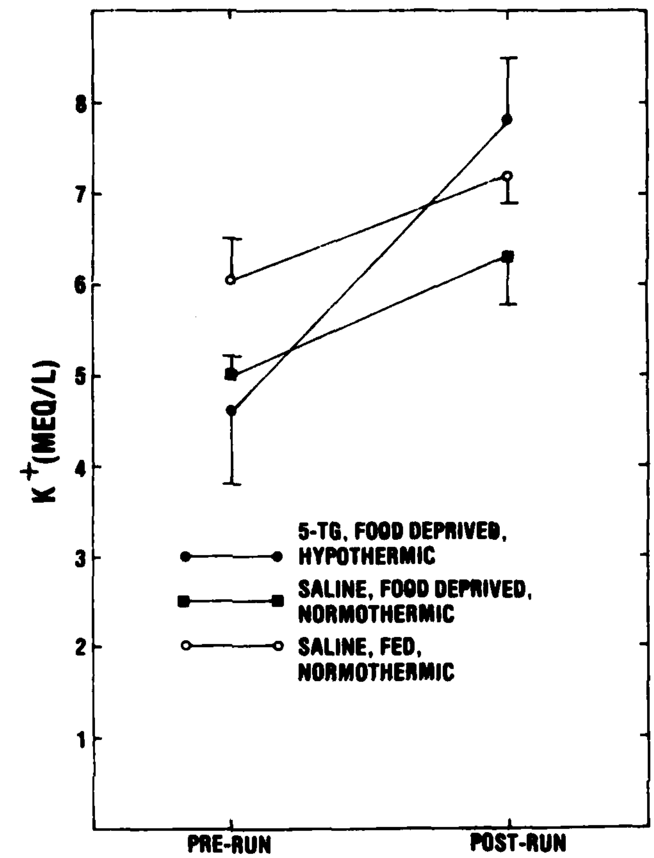

Figure 6. Effects of 5-TG administration and food deprivation on the plasma potassium concentrations immediately before and after exercise to hyperthermic exhaustion in a hot environment.

The remaining results present corresponding data for animals (n=9, 280-325 g) which were rendered hypothermic by intravenous administration of low doses (2.5 mg) of amphetamine, and likewise exercised to hyperthermic exhaustion. The results demonstrated in Figure 7 are quite similar to those noted for animals treated with 5-TG. In fact data depicted in Table 2 show a striking similarity to those depicted in Table 1 for 5-TG treated animals. The endurance capacity is significantly increased ($p < .001$), increments in Tre for the

initially hypothermic rats are significantly ($p < .001$) greater, and increments in skin temperature are significantly larger ($p < .001$) for the initially normothermic rats. This is, once again, indicative of a tendency to reduce peripheral cooling since core temperature is below normal levels. Figure 8 demonstrates the effects of amphetamine administration and pre-induced hypothermia on the levels of plasma glucose and CPK immediately prior to and subsequent to exercise in the heat to hyperthermic exhaustion. Surprisingly, despite the increased exercise times, levels of these compounds are quite similar to those noted for control animals which had been administered only physiological saline, but otherwise treated identically. This is also true of the results depicted in Figure 9 which show that with respect to plasma levels of lactate and potassium, the responses to exercise in the heat are quite similar to those of control animals.

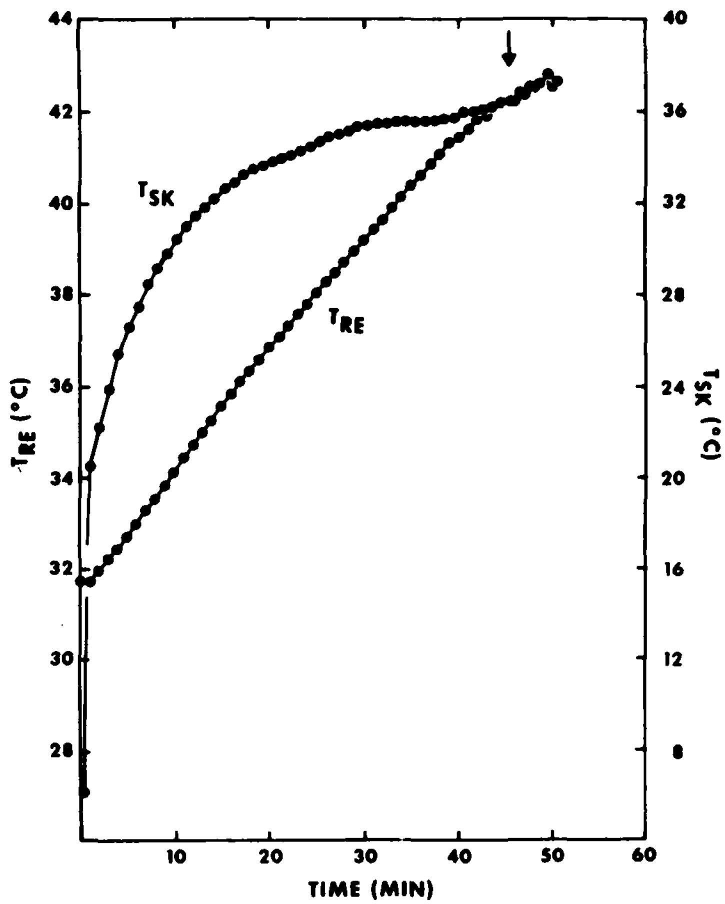

Figure 7. Effects of hypothermia induced by administration of 2.5 mg amphetamine on the Tre and Tsk responses to exercise in the heat.

TABLE 2

Summary of the Data Presented in Figure 7

	TIME ON TREADMILL (MINUTES)	RECTAL TEMPERATURE MAXIMUM (°C)	ΔT_{RE}/MIN ON TREADMILL (°C)	SKIN TEMPERATURE MAXIMUM (°C)	ΔT_{SK}/MIN ON TREADMILL (°C)
CONTROL NORMOTHERMIC					
$\bar{X}$	32.92	42.61	.171	37.41	.984
$SE_{\bar{X}}$	1.65	.09	.007	.43	.043
d-AMPHETAMINE HYPOTHERMIC					
$\bar{X}$	45.22	42.60	.243	36.36	.674
$SE_{\bar{X}}$	1.15	.07	.01	.34	.023
t	5.559	.04	5.985	1.77	5.562
p	< .001	NS	< .001	NS	< .001

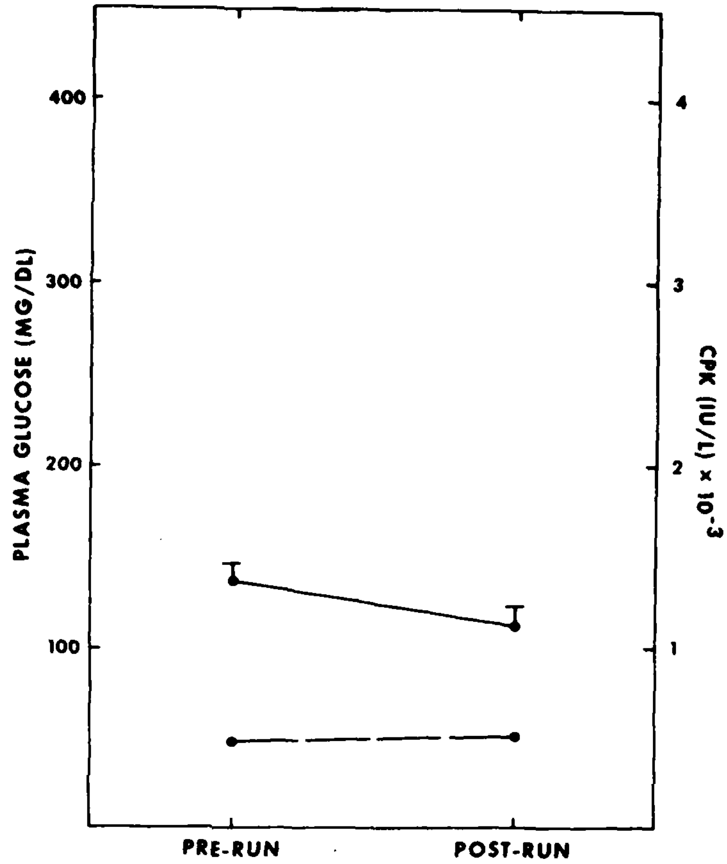

Figure 8. Effects of amphetamine administration on the levels of plasma glucose (solid line) and CPK immediately prior to and following exercise in the heat to hyperthermic exhaustion.

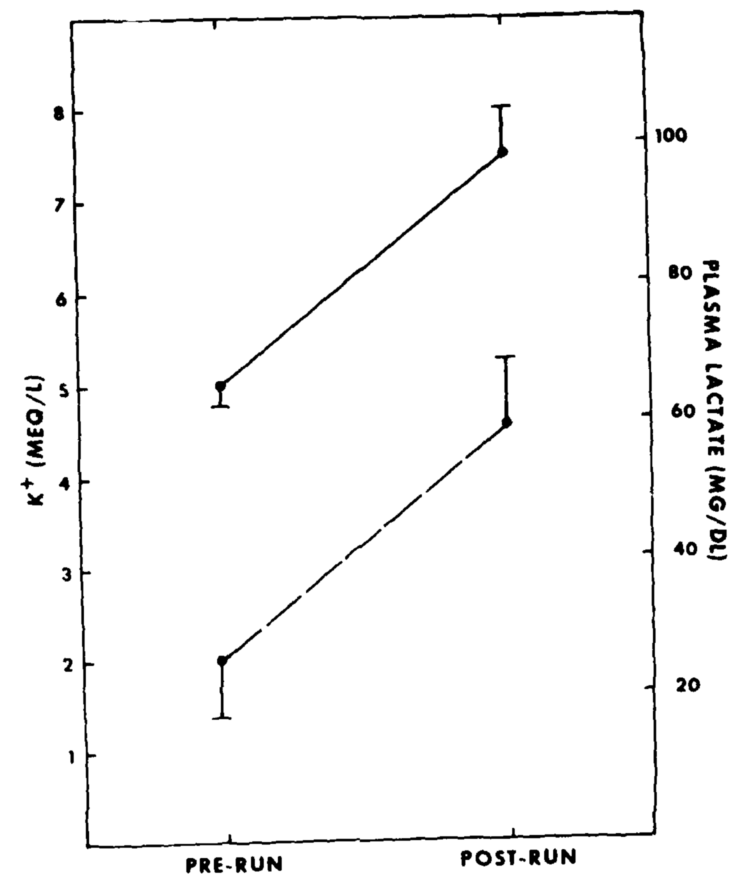

Figure 9. Effects of amphetamine administration on the levels of plasma potassium (solid line) and plasma lactate prior to and immediately following exercise in the heat to hyperthermic exhaustion.

These data confirm our earlier observations that pre-induced hypothermia can significantly increase the endurance capacity of animals exercising in the heat. However, in these animals peripheral heat loss is reduced while homeostatic mechanisms are operative to restore initially hypothermic temperatures to normothermic. Selective effects on the clinical chemical indices of heat injury did not appear to be related to changes in the extent of the heat/exercise injury.

We anticipate that research on pharmacological means to reduce the physiological cost of work in the heat will be continued in the Heat Research Division. These studies are essentially investigations on the pathophysiology and pathochemistry of heat injury, and it is our hypothesis that additional information on the mechanisms of heat injury will be useful in devising new methods for the diagnosis, prevention, and treatment of heat/exercise induced injuries.

Publications:

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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 005 Models of Heat Disabilities: Preventive Measures

Study Title: Acclimatization to Exercise in Dry Heat: Active Men vs. Active Women

Investigator: Donald H. Horstman, Ph.D.

Background:

From earlier studies of sexual differences in performance of an physiological responses to exercise in hot environments, and acclimatization thereto, it was generally concluded that women had inferior performance capacity, reached physiological limits at a faster rate and did not acclimatize as well, when compared to men (1,2,3). Conclusions from these previous studies are complicated by three factors, exercise was performed by both sexes at the same absolute intensity, physical fitness levels, as indicated by maximal oxygen consumption ($\dot{V}O_2$ max) and physical activity pattern were not considered. For exercise under hot humid (4) and hot dry (5) conditions, the magnitude of rectal temperature (Tr) increase, thus heat storage, has been observed to be a positive linear function of relative exercise intensity (% $\dot{V}O_2$ max). In the general population, $\dot{V}O_2$ max for women is about 20% less than that for men (6). It is likely that, in earlier studies (1,2,3), women were exercising at a much higher % $\dot{V}O_2$ max than were the men and the effects of exercise related influences, independent of environmental temperature, on indices of heat stress and performance was likely greater for the women than for the men. Indeed, Weiman et al. (7) found that, when compared to sedentary men, active women had superior performance of, lesser indices of heat stress for and a greater extent of acclimatization to exercise of equal absolute intensity in humid heat.

To determine the existence of true sexual differences for performance of and physiological responses to exercise in the heat, exercise must be equated on a relative basis for all subjects. Moreover, comparisons must be made for men and women of similar physical fitness levels with similar activity patterns relative to physical training. Paolone et al. (8) compared active, physically fit men and women and found no differences in physiological responses to exercise

at equal relative intensity in humid heat (55% relative humidity). Kamon and Avellini (9) recently reported that, for exercise at equal relative intensity in humid heat (65% relative humidity), active physically fit men and women performed about equally both before and after acclimatization. With the exception of sweat rate, which was greater for the men, physiological responses and especially heat storage were also about equal between the two sexes. These experiments (8,9) were conducted under conditions of high humidity where sweating is a less significant contribution to heat loss.

It is not readily apparent whether this equality of the sexes, as observed by Paolone et al. (8) and Kamon and Avellini (9) would be maintained for exercise under conditions of dry heat. Sweat rate for men has been observed to be much higher initially and to increase to a greater extent with acclimatization than for women performing the same exercise under the same conditions of environmental heat (2,3,7,9). Since sweating is the primary mechanism for heat loss under conditions of low ambient humidity, it is possible that, due to this greater capacity for sweating, men may be functionally better suited for exercise in dry heat than are women. The purpose of this study was to compare performance of and physiological responses to exercise of equal relative intensity in dry heat between active men and active women of near equal physical fitness levels.

Progress:

Six male and four female unacclimatized, active volunteers served as subjects for this study. Mean $\pm$ S.E. height, weight and body surface area for the men (176 ± 4 cm, 77.0 ± 3.5 kg, 1.98 ± 0.06 m^2) were significantly greater ($p < 0.01$) than that for the women (166 ± 4 cm, 66.8 ± 3.9 kg, 1.75 ± 0.08 m^2). However, there was no difference between men and women for the ratio of body surface area to body weight, 258 ± 6 and 262 ± 4 cm^2/kg, respectively.

$\dot{V}O_2$ max was determined for all subjects both before and after heat acclimatization procedures. These data are presented in Table 1. Although $\dot{V}O_2$ max for the men was statistically greater than that for the women, the actual differences (about 3.5 ml/kg•min) was quite small and of doubtful physiological significance when comparing physical fitness levels between the two sexes. Moreover, the magnitude of $\dot{V}O_2$ max observed for the women ($>$ 47 ml/kg•min) is well in excess of normal values, indicating the women were in

excellent physical condition. No significant changes in any of the maximal measurements occurred as a result of the acclimatization procedures.

TABLE 1

Pre and post-acclimatization measurements during maximal exercise for men (n=6) and women (n=4).

			Men	Women
$\dot{V}_{O_2}$	liters/min	Pre	3.96 ± 0.11	3.15 ± 0.22
		Post	3.91 ± 0.09	3.22 ± 0.15*
$\dot{V}_{O_2}$	ml/kg • min	Pre	51.4 ± 1.2	47.2 ± 1.3
		Post	51.3 ± 1.0	48.2 ± 0.5*
$\dot{V}_E$	liters/m^2 • min	Pre	70.2 ± 2.5	58.9 ± 3.8
		Post	69.7 ± 2.1	60.6 ± 1.9*
R		Pre	1.17 ± 0.02	1.15 ± 0.03
		Post	1.17 ± 0.01	1.15 ± 0.03
HR	beats/min	Pre	191 ± 3	192 ± 4
		Post	188 ± 3	190 ± 4

Values are means ± S.E.

*F ratio (2 x 2 ANOVA) for differences between men and women significant at $p < 0.01$.

For heat acclimatization, subjects exercised in the heat for eleven days. They performed continuous bicycle exerciseat 40% $\dot{V}O_2$ max for a maximum of 120 min under environmental conditions of 45°C DB/23°C WB, minimal airflow. Fluids were replaced at 15 min intervals throughout the exercise.

Heart rate (HR) and Tr were measured at 5 min intervals while cardiac output ($\dot{Q}$), stroke volume (q_{st}), minute ventilatory volume ($\dot{V}_E$), respiratory exchange ratio (R) and $\dot{V}O_2$ were determined at 30 min intervals and upon termination of exercise. Just prior to beginning, at 30 min intervals during and upon termination of exercise, a 6 ml blood sample was obtained from an indwelling anticubital venous catheter for the determination of hematocrit (HCT), plasma osmolarity (OSM), plasma protein (PROT) and lactate (LAC) concentrations. Dry body weight was measured to the nearest 0.1 kg immediately before and after exercise. Body weight difference was added to the weight of fluids given, corrected for respiratory and metabolic water loss, and expressed per unit time as an estimate of mean whole body sweat rate ($\dot{m}_{sw}$).

Only data obtained on the first, sixth and eleventh day of acclimatization were used to test for sexual differences. Results obtained for the women were statistically compared to those obtained for the men by multi-factorial repeated measures analysis of variance (ANOVA).

The temporal pattern of response for HR and Tr during exercise in the heat on the first, sixth and eleventh days of acclimatization are presented in Figure 1. Presentation is restricted to those times for which data were available for all ten subjects. On Day 1, the women maintained HR about 15 bpm greater than the men throughout the exercise, while on Days 6 and 11 there were no differences in HR between the sexes. Of interest is the difference between men and women in the pattern of response of Tr on all three days of testing. The women exhibited immediately progressively increasing Tr, while for the men there was about a 15 min delay before Tr began to increase. The rate of increase of Tr was faster for the men so that Tr was equal for men and women at about 50 min. On Days 6 and 11, Tr for men increased to significantly higher levels than for women.

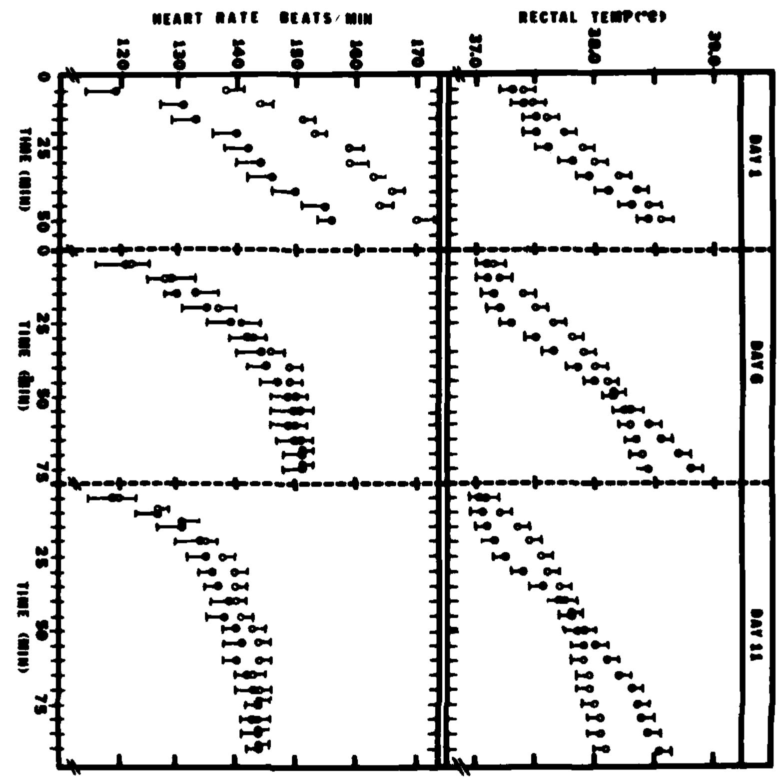

Figure 1. Rectal temperature and heart rate (mean ± S.E.) as functions of time for 6 men (●) and 4 women (○) during exercise in dry heat on Days 1, 6 and 11 of acclimatization.

The rate of increase of Tr and HR, along with performance times and sweating data are presented in Table 2. Prior to acclimatization (Day 1) there were no differences between the men and women for performance time, rate of increase of Tr ($\mathring{\Delta}$Tr), rate of increase of HR ($\mathring{\Delta}$ HR) or for $\dot{m}_{sw}$ per ^{o}C increase of Tr ($\dot{m}_{sw}/\mathring{\Delta}$ Tr); $\dot{m}_{sw}$ was greater for the men than for the women.

TABLE 2

Performance time, sweat rate ($\dot{m}_{sw}$), rate of increase of Tr ($\dot{\Delta}$ Tr) and HR ($\dot{\Delta}$ HR), and $\dot{m}_{sw}$ per ^{o}C increase of Tr ($\dot{m}_{sw}/\dot{\Delta}$ Tr) for men (n=6) and women (n=4) on Days 1, 6 and 11 of acclimatization.

			Day 1	Day 6	Day 11
Performance Time	(min)	Men	74 ± 10	98 ± 10	100 ± 6
		Women*	83 ± 8	120 ± 0	120 ± 0
$\dot{m}_{sw}$	($g/m^2 \cdot h$)	Men	569 ± 37	635 ± 56	694 ± 76
		Women*	461 ± 38	490 ± 52	517 ± 47
$\dot{\Delta}$ Tr	(^{o}C/h)	Men	1.5 ± 0.2	1.1 ± 0.1	0.8 ± 0.1
		Women*	1.4 ± 0.2	0.7 ± 0.1	0.5 ± 0.0
$\dot{\Delta}$ Hr	(bpm/h)	Men	42 ± 5	25 ± 4	17 ± 2
		Women	39 ± 6	22 ± 3	15 ± 2
$\dot{m}_{sw}/\dot{\Delta}$ Tr	($g/m^2 \cdot {}^{o}C$)	Men	376 ± 51	567 ± 58	839 ± 69
		Women*	341 ± 40	722 ± 45	976 ± 79

Values are means ± S.E.

*F ratio (2 x 3 ANOVA) for differences between men and women significant at $p < 0.05$.

F ratio (2 x 3 ANOVA) for differences among days of acclimatization significant at $p < 0.01$.

Both sexes exhibited acclimatization as evidenced by increases in performance time and $\dot{m}_{sw}$ and decrease in $\dot{\Delta}$ Tr and $\dot{\Delta}$ HR on Days 6 and 11. At the midpoint of acclimatization (Day 6), the women had better performance times than the men. Although the men still had greater $\dot{m}_{sw}$ than the women, $\dot{\Delta}$ Tr for the women was significantly less than for the men and $\dot{m}_{sw}/\dot{\Delta}$ Tr for the women was greater than for the men. Neither HR nor $\dot{\Delta}$ HR was different between the sexes.

Upon completion of acclimatization (Day 11), the women still had better performance times than the men. Again, the men had greater $\dot{m}_{sw}$ than the women, but again $\mathring{\Delta}$ Tr for the women was less and $\dot{m}_{sw}/\mathring{\Delta}$ Tr was greater than for the men. Neither HR nor $\mathring{\Delta}$ Tr was different between the sexes.

Figure 2 continues metabolic and cardiovascular parameters measured during exercise in the heat on the first, sixth and eleventh days of acclimatization. Oxygen consumption for the men was slightly higher than that for the women; as $\dot{V}O_2$ max was also slightly higher for men than for women. However, there was no sexual difference for the ventilatory equivalent for oxygen consumption ($\dot{V}_E/\dot{V}O_2$), it being about 35 for the men and about 33 for the women; this indicates that the magnitude of $\dot{V}_E$ was appropriate for the magnitude of $\dot{V}O_2$. There were no significant sexual differences for LAC or R.

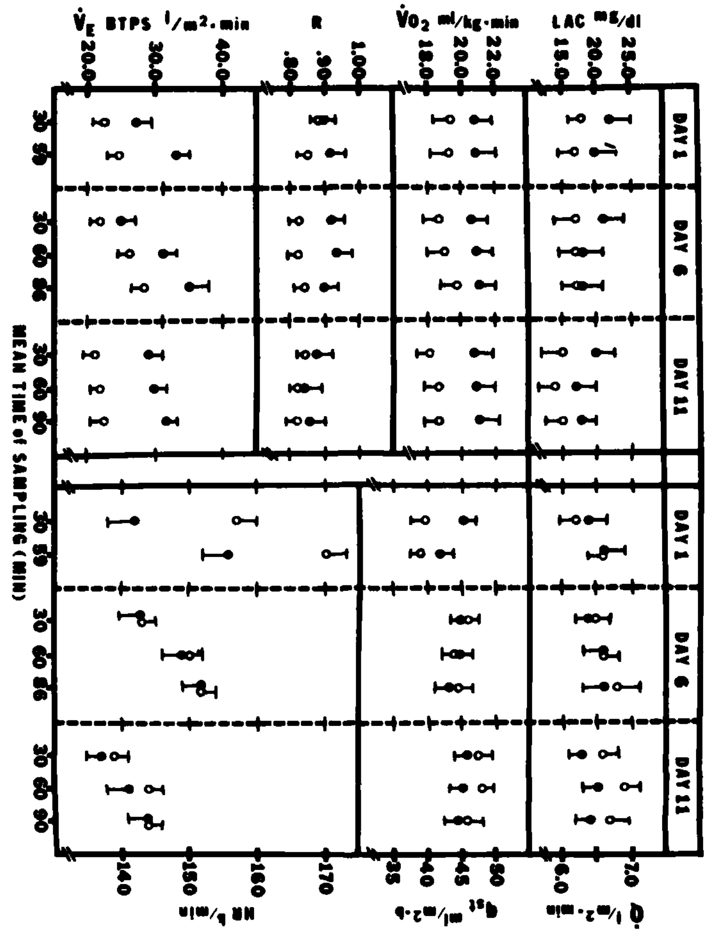

Figure 2. Ventilatory, metabolic and cardiovascular parameters (mean ± S.E.) as functions of time for 6 men (●) and 4 women (○) during exercise in dry heat on Days 1, 6 and 11 of acclimatization.

Cardiac output did not change throughout exercise, nor were there any changes with acclimatization. There were no differences between men and women when $\dot{Q}$ was standardized for body surface area. Since $\dot{Q}$ was relatively stable q_{st} varied with the inverse of HR, notably q_{st} decreased as HR increased during exercise and q_{st} increased as HR decreased with acclimatization. On

Day 1, the men had greater q_{st} than did the women; sexual differences were not observed as the subjects became acclimatized.

As indicated in Table 3, resting HCT for the women was less than that for the men on all test days; no significant changes in HCT were observed with acclimatization. No differences in resting PROT or plasma osmolarity were present between the men and women or among the days of acclimatization. As indicated in Figure 3, a significant increase in plasma protein concentration occurred during exercise on all test days; no significant changes in HCT or plasma osmolarity were observed.

TABLE 3

Resting hematocrit, plasma osmolarity and plasma protein concentration for men (n=6) and women (n=4) on Days 1, 6 and 11 of acclimation.

			Day 1	Day 6	Day 11
Hematocrit	(%)	Men	44.2 ± 0.7	43.2 ± 0.9	43.6 ± 0.5
		Women*	39.0 ± 1.1	39.2 ± 0.7	38.2 ± 1.1
Plasma Osmolarity	(mOsm/kg)	Men	293 ± 1	291 ± 2	291 ± 1
		Women	292 ± 2	290 ± 1	294 ± 2
Plasma Protein Concentration	(g/dl)	Men	7.5 ± 0.2	7.5 ± 0.2	7.4 ± 0.2
		Women	7.8 ± 0.2	7.7 ± 0.2	7.5 ± 0.2

Values are means ± S.E.

*F ratio (2 x 3 ANOVA) for differences between men and women significant at $p < 0.01$

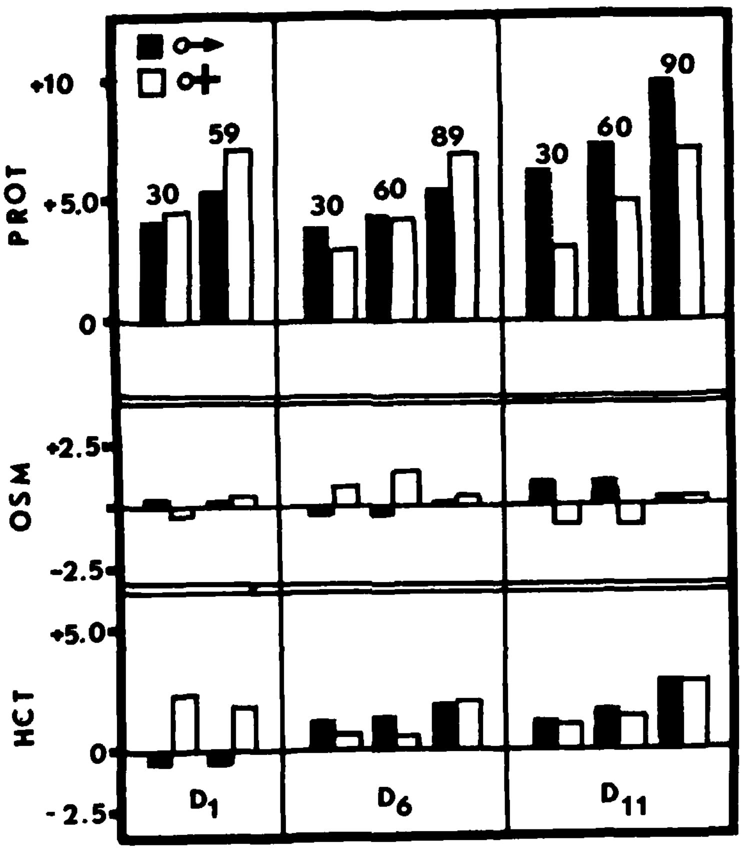

Figure 3. Percentage changes from rest for hematocrit (HCT), plasma osmolarity (OSM) and plasma protein concentration (PROT) as functions of time (numbers above bars are time in minutes) for men (n=6) and women (n=4) during exercise in dry heat on Days 1 (D_1), 6 (D_6) and 11 (D_{11}) of acclimatization.

It was concluded that active women perform exercise of equal relative intensity in dry heat as well as active men. Moreover, active women acclimatized to exercise of equal relative intensity in dry heat at a faster rate or to a greater extent than did active men. Ventilatory, metabolic and cardiovascular differences between the sexes were minimal and these measures

were relatively stable throughout exercise on each day and among the days of acclimatization. Changes in plasma volume played no role in the acclimatization process for these active subjects.

Even though heat storage and cardiovascular functions during exercise in dry heat were relatively equal between the sexes, sweat rates for the men were significantly greater than for the women. These observations seriously question a beneficial role for excessively high sweat rates relative to heat loss during work under hot, dry conditions. Moreover, it is possible that excessive sweating on the part of men could result in a faster rate of dehydration than women under the combined stresses of work, heat and fluid deprivation. Dehydration compromises heat loss mechanisms, seriously affecting both work performance and heat storage under conditions of extreme environmental heat. It may be that women may be better suited for work in hot environments where fluid sources were limited. We are planning to compare the effects of fluid deprivation and resultant dehydration between men and women of equal physical fitness levels on work performance in the heat and related physiological parameters.

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Program Element:	6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	005 Models of Heat Disabilities: Preventive Measures
Study Title:	Reproducibility of Sweat Onset and Sensitivity During Exercise at Thermoneutrality
Investigators:	Donald H. Horstman, Ph.D. and Omar Hottenstein, SP5

Background:

Nadel et al. (6) have described a method to determine threshold and sensitivity for sweating as a function of increasing esophageal temperature during exercise in a thermoneutral environment. This method is sensitive to both physical training and heat acclimatization and offers some distinct advantages over the more commonly used methods (heat exposure with or without exercise) for evaluating sweating responses. The time to administer the test is quite short, requiring only about 30 minutes. Procedures are relatively simple, requiring equipment of minimal sophistication. Testing is conducted at thermoneutral ambient temperature (25°C) allowing evaluation of thermoregulatory function independent of degree of external heat stress and offering the potential for repeated testing at short time intervals without the complicating influences of heat acclimatization.

It is our intent to use this test as a primary criterion for prediction of exercise performance in the heat in large populations. As such, we were especially concerned with the reproducibility of results obtained from naive subjects. In previous studies, in which this test, or some facsimile thereof, was utilized, reliability was either assumed and a single test performed (5), or duplicate tests were performed (6,7,9). We felt a formal evaluation of the day to day reproducibility of results obtained from this test was warranted. Moreover, circadian variations in results obtained have been suggested specifically for this test, however comparisons were made only between experiments conducted at night and during the day (9). The purposes of the present study were to evaluate the day to day reproducibility (reliability) of the test; to determine the pattern of circadian variations during a limited portion of the day (0800 - 1700 hours), a time frame within which experimental testing is normally conducted; and to

determine if prior testing on the same day influences results obtained from testing later in the day.

Progress:

Maximal oxygen consumption ($\dot{V}O_2$ max) was determined for each subject on the bicycle ergometer by an interrupted procedure similar to that described by McArdle et al. (3). From $\dot{V}O_2$ measurments during submaximal exercise, relative intensities approximating 70% $\dot{V}O_2$ max were derived for further experiments.

To establish esophageal temperature (Tes) for sweating onset and change of sweat rate per $^{\circ}$C rise of Tes (sensitivity), subjects cycles for 8 to 15 min at approximately 70% $\dot{V}O_2$ max. Mean ambient temperature was 25°C (range 24 to 26°C); relative humidity was approximately 25%. Measures of Tes were recorded at 30 sec intervals from a copper-constantan thermocouple at heart level in the esophagus. Skin temperatures from the chest (Tch), lateral upper arm (Tarm) and anterior thigh (Tth) were measured at 30 sec intervals with copper-constantan thermocouples; mean skin temperature ($\bar{T}_{sk}$) was calculated according to Roberts et al. (7). Sweating was continuously recorded by resistance hygrometry from 12 cm^2 sweat capsule on the chest over the seventh and eighth ribs in the mid-clavicular line. This procedure, described in detail by Nadel et al. (4), consists of passing an air stream of constant water content and flow rate over the encapsulated area of the skin and measuring the change of water content of the air.

From linear plots of sweat rate ($\dot{m}_{sw}$) as a function of Tes, Tes for sweating onset was derived as the O $\dot{m}_{sw}$ intercept and sweat sensitivity as the slope of the line. Heart rate was measured at 5 min intervals from ECG tracings and monitored periodically throughout these tests.

To ascertain the reliability of this test, subjects performed the test daily for three consecutive days; each subject performed the test at the same time each day. To determine circadian variations, subjects performed the test once daily on five different days at 0800, 1000, 1200, 1400 and 1600 hours. To determine if prior testing on the same day influences results from testing performed later in the day, subjects performed the test at 0800, 1030, 1300 and 1530 hours on the same day.

The mean $\dot{V}O_2$ max for the subjects tested in this study was 3.61 liters/min (S.E. $\pm$ 0.50) or 49.1 ml/kg • min (S.E. $\pm$ 1.8); mean maximal HR was 185 beats/min (S.E. $\pm$ 3). For the sweating tests bicycle exercise was performed at a mean intensity of 975 KPM/min (S.E. $\pm$ 45). Estimated $\dot{V}O_2$ for this exercise was 2.56 liters/min (S.E. $\pm$ .36); this corresponds to a mean relative exercise intensity of 71% $\dot{V}O_2$ max (S.E. $\pm$ 2).

In the three tables in this report, heart rate is the mean of HR measured at 5 min, while $\bar{T}_{sk}$ is the mean for all measures of $\bar{T}_{sk}$ throughout exercise. Table 1 depicts results from tests performed daily on three consecutive days.

TABLE 1

Means $\pm$ S.E. for Results from Tests Performed at the Same Time on Three Consecutive Days (n=6)

	Heart Rate Beats/min	$\bar{T}_{sk}$ °C	Sweat Onset °C	Sweat Sensitivity mg/cm^2 • min/°C
Day 1	142 $\pm$ 3	32.4 $\pm$ 0.2	37.24 $\pm$ 0.13	0.82 $\pm$ 0.11
Day 2	144 $\pm$ 4	32.7 $\pm$ 0.2	37.27 $\pm$ 0.12	0.78 $\pm$ 0.12
Day 3	144 $\pm$ 4	32.5 $\pm$ 0.3	37.34 $\pm$ 0.13	0.76 $\pm$ 0.11

One-way repeated measures analysis of variance revealed no statistical differences for any of the measures during the three test days. Test-retest coefficients of correlations for sweat onset and sensitivity comparing any two combinations of test days were in excess of 0.90. It was concluded that results from this test were reliable.

Results from tests performed at different times on different days are presented in Table 2.

TABLE 2

Means $\pm$ S.E. for Results from Tests Performed at Different Times on Different Days (n=5)

Time	Heart Rate Beats/min	$\bar{T}_{sk}$ °C	Sweat Onset °C	Sweat Sensitivity mg/cm^2 • min/°C
0800	144 $\pm$ 2	32.5 $\pm$ 0.2	37.13 $\pm$ 0.09	0.68 $\pm$ 0.07
1000	143 $\pm$ 3	32.4 $\pm$ 0.2	37.25 $\pm$ 0.99	0.68 $\pm$ 0.09
1200	146 $\pm$ 5	32.3 $\pm$ 0.2	37.22 $\pm$ 0.12	0.68 $\pm$ 0.08
1400	146 $\pm$ 3	32.5 $\pm$ 0.2	37.27 $\pm$ 0.08	0.68 $\pm$ 0.10
1600	146 $\pm$ 3	32.6 $\pm$ 0.3	37.29 $\pm$ 0.09	0.70 $\pm$ 0.10

One-way repeated measures analysis of variance revealed no statistical differences for any of the measures for any time of day. Although not statistically different, Tes for sweat onset was lower at 0800 than at any other time. Test-retest coefficients of correlation for sweat onset and sensitivity comparing any two combinations of test times were in excess of 0.85.

Finally, results comparing results from tests performed at different times on the same day are presented in Table 3.

TABLE 3

Means $\pm$ S.E. for Results from Tests Performed at Different Times on Different Days (n=5)

Time	Heart Rate Beats/min	$\bar{T}_{sk}$ °C	Sweat Onset °C	Sweat Sensitivity mg/mc^2 • min/°C
0800	144 $\pm$ 2	32.5 $\pm$ 0.2	37.13 $\pm$ 0.09	0.68 $\pm$ 0.07
1000	143 $\pm$ 3	32.4 $\pm$ 0.2	37.25 $\pm$ 0.99	0.70 $\pm$ 0.09
1200	146 $\pm$ 5	32.3 $\pm$ 0.2	37.22 $\pm$ 0.12	0.68 $\pm$ 0.09
1400	146 $\pm$ 3	32.5 $\pm$ 0.2	37.27 $\pm$ 0.08	0.68 $\pm$ 0.10
1600	146 $\pm$ 3	32.6 $\pm$ 0.3	37.29 $\pm$ 0.09	0.70 $\pm$ 0.10

Again, no statistical differences for any of the measures for any time of day were indicated by one-way repeated measures analysis of variance. Again, although not statistically different, Tes for sweat onset was lower at 0800 than at any other time. Test-retest coefficients of correlation for sweat onset and sensitivity comparing any two combinations of test times were also in excess of 0.85.

Previous investigators (1,28) have reported that during early morning exposures to heat without exercise, subjects began sweating at lower rectal, tympanic or mean body temperatures than during the same exposure in late morning, afternoon or evening. For the specific test which we evaluated, Wenger et al. (9) observed Tes for sweat onset to be lower between 0400 and 0530 hours as compared to that observed between 1200 and 1630 hours. No difference in sweat sensitivity was observed between early morning and afternoon. Our interests were in reproducibility of results within a time frame which we normally conduct experimental testing. Our results indicate that Tes for onset of sweating and sweat sensitivity were insensitive to time of day within the limits 0800 through 1600 hours. This was true whether tests were administered on different or the same day, as prior testing on the same day did not influence results obtained from testing later in the day. It should be noted that Tes for onset of sweating tended to be lower at 0800 and, as a precaution, it is recommended that testing not be conducted prior to 0900 hours. We plan to test the validity of this procedure by correlating results obtained with physiological responses to exercise in the heat.

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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 005 Models of Heat Disabilities: Preventive Measures

Study Title: The Role of Heat Acclimatization in Preventing Heatstroke Mortality

Investigators: Roger W. Hubbard, Ph.D., Wilbert D. Bowers, Ph.D. and Milton Mager, Ph.D.

Background:

Of the recognized heat disorders, the most serious is acute heatstroke. In contrast to the form that characteristically affects the ill or the aged, exertion-induced heatstroke can strike down healthy young individuals (soldiers) engaged in some type of physical activity. In 1923, Adolph and Fulton (1) suggested that the primary cause of heatstroke was circulatory failure: "We have, then, in exposure to high temperature, a type of circulatory failure which would have to be included under the general category of shock. ...This type of circulatory failure is believed by the present authors to constitute heatstroke."

The stress imposed by high ambient temperatures is translated into physiological strain primarily on the cardiovascular system which is responsible for the transfer of excess heat from the body core to the skin. Recent evidence from this laboratory (2,3,4,5) indicates that under the combined stress of high ambient temperatures and, simultaneously, exhaustive physical exercise the resultant strain and possibly overload to the cardiovascular system substantially lowers the threshold for both heat injury and heatstroke mortality. One hypothetical explanation for this result is the possibility that exhaustive physical exercise, by worsening circulatory collapse and metabolic acidosis predisposes tissue to hyperthermic injury. Thus, any measure designed to strengthen or reenforce the cardiovascular response to hyperthermia could forestall or prevent heat injury.

Over two hundred years ago, J. Lind (6) emphasized - that habituation or natural acclimatization to hot environments reduced the risk of heat injury. More recently, Leithead and H. R. Lind (7) state: "Acclimatization is achieved simply by exposing men to heat." This evidently assumes that men exposed to

hot environments will at least attempt normal working activity and this statement is thus an over-simplification in the strictest sense. In the early 1960's researchers from this laboratory (8) reported that many of the benefits of natural acclimatization could be achieved artifically by short, daily exposures to exercise in the heat. The resultant physiological changes or adaptations to high ambient temperatures are often referred to as "indices" of heat acclimatization and include, in response to successive exposures, a progressive reduction of core temperature and pulse rate with a concomitant increase in the amount of sweat produced. These adaptations clearly have a cardiovascular component which are consistent, at least hypothetically, with an increase in circulating plasma volume. For obvious reasons, the benefits of this human acclimatization process in preventing or forestalling severe heat injury have not been experimentally defined. By developing a rat heatstroke model, and at the same time, by defining the many similarities between human and animal heat injury syndromes, we are now in a more credible position to define the degree to which an artificial acclimatization process can prevent or forestall serious heat disorders. Furthermore, it is hoped that essential differences between acclimatized and non-acclimatized animals following hyperthermic episodes will provide insights into new rationales for therapy and means for preventing acute heatstroke mortality.

Prior to combining the stresses of both heat and physical exercise, a preliminary investigation was conducted to measure the acclimatization response of 34 fed unanesthetized laboratory rats to short daily exposures to heat alone. The results were reported in the FY 1978 Annual Progress Report. Since that time, we have continued the experiment and now have data from 96 animals. On each of five successive days, experimental rats ($\sim$500 g; n = 54) were removed from their cages (26C), were fitted with rectal thermocouples (6.5 cm) and were restrained in an environmental chamber at 41.5C until at t core of 40.4C was achieved. Controls (n = 42) were treated similarly, but restrained at 26C without resultant hyperthermia. Following a 48 h rest plus a 24 h fast (72 h total), all rats were restrained at 41.5C until a hyperthermic exposure calculated to produce an LD 90 within 24 h was achieved ($>$ 60 deg•min above a t core of 40.4C). After removal from the heat rats were monitored at 26C and were allowed water but no food. All rats alive after 24 h were counted as survivors. The results of short, daily bouts of heat stress on the acclimatization parameters (indices) are shown in Table 1.

TABLE 1

Heat Stress/Acclimatization Parameters: Stress 1 to Stress 5

	Heat Time	Heat Rate	Cool Rate	Pre-Stress Hct.	Pre-Stress Prot.	Post-Stress Heart Rate	Post-Stress Blood Pressure
Stress 1	25	.098	.058	48	7.1	395	157
(n)	± 6	± .027	± .019	± 2.6	± 0.3	± 48	± 13
	(54)	(54)	(54)	(30)	(30)	(30)	(26)
Stress 5	34*	.084*	.073*	48	7.3*	388	157
(n)	± 8	± .022	± .020	± 1.6	± 0.3	± 36	± 12
	(54)	(54)	(54)	(29)	(29)	(29)	(29)

*$p < .05$ for student t test between the mean ± S.D. and the mean immediately above it.

The results of the five successive heat exposures on the 54 experimental rats are shown above. During successive heat exposures (stress 1 vs. stress 5), the time at 41.5C ambient to reach a core temperature of 40.4C was significantly increased (25 vs 34 min). For example, during stress 5 the mean core temperature at 25 minutes (i.e. total time for stress 1) was 39.5 ± 0.6C. This progressive reduction in core temperature with successive exposures to a hot environment is a classical indicator of acclimatization and represents a significant reduction in heating rate from 0.098 to 0.084 C per minute. There was also a significant increase in cooling rate, post heating. Although plasma protein was increased slightly, there were no indications (Hct, B.P., or H.R.) that plasma volume was expanded. This might have been expected since the experimental design did not allow for the measurement of these parameters at equivalent times (i.e. 25 min) but only at equivalent core temperatures (40.5 ± 0.1, n = 54). Thus, the increase in cooling rate between stress 1 and stress 5 could be due to some other factor(s) resulting in an improved cardiovascular response to core heating.

The effectiveness of the acclimatization response to subsequent lethal heat exposure is demonstrated in Table 2.

TABLE 2

Acclimatization: Resistance to Lethal Heat Exposure (>LD90)

	n	Total[1] Area	Max Tc	Heating Wt. Loss g	% Mort.	Heating Time (minutes)	Heating Rate (°C/min)	Cooling Rate (°C/min)	E.O.H. H.R.	E.O.H. HCT	E.O.H. PROT
Experimental	54	61.1	42.1	17.8	13/54	84	.059	.101	508	48	7.2
		± 15.0	± 0.4	± 7.3	24%	± 50	± .024	± .030	± 60	± 4	± 0.8
		LD 93.4	LD 14.4								
Control	42	63.5	42.4*	12.8*	29/42	55*	.088*	.094	522	51*	7.1
		± 13.6	± 0.4	± 4.9	69%	± 15	± .028	± .021	± 46	± 3	± 0.7
		LD 99	LD 50.1								

[1]Core temperature was measured at 2 to 6 minute intervals and thermal area was calculated when core temperature exceeded 40.4°C using the formula thermal area (deg•min) ≈ Σ time interval (2 to 6 min) x 1/2 (°C above 40.4°C) at start of interval + °C above 40.4°C at end of interval.

*$p < .05$ for student t test between the mean ± S.D. and the mean immediately above it.

As shown above, the prior heat exposures of the experimental group resulted in a significant reduction in the rate of core heating when re-exposed to 41.5C ambient. A training effect on the controls is evident since their heating rate (their sixth exposure to the chamber but their first exposure with heating) was less than the experimental group on stress 1 (0.088 vs. 0.098). Despite the training effect, the heat-stressed rats had a significantly lower heating rate than the controls (0.059 vs. 0.088). As a consequence, the heating time to reach a hyperthermic area in excess of an LD 90 was significantly prolonged and these rats lost more body weight. Despite this, the experimental group maintained significant reductions in both hematocrit and core temperature. The reduced rate of hemoconcentration in spite of a significantly longer exposure time and body weight loss is consistent with a greater flux of extravascular fluid into the intravascular space during heating. As a result, there were less mortalities in the acclimatized group. The mortality rate (24%) was also less than could be predicted from the arithmatic mean of either measure of mortality (area vs. t core). On the other hand, the mortality rate of control rats (69%) appeared in reasonable agreement with the mean of the two measures of lethality ([LD 99 + LD 50]÷2 = LD 74). The use of a combined index to predict mortality (calculated as the average of the lethal dose sustained according to previously published max t core and thermal area curves) deserves comment. The advantage of an acclimatization process is a prolongation of exposure time to heat or hyperthermia with some reduction in the usual intensity of core heating. This can be inferred from the most obvious indicator of acclimatization, a reduction in t core for a given exposure. Stated in another way, one could anticipate that acclimatized individuals would accumulate a greater hyperthermic exposure in degree-minutes for any given increase in the t core. Since both measurements have been used to predict mortality, and since the acclimatization technique was designed to disassociate one from the other, we have employed a statistical technique, the Mahalanobis D^2 statistic, to test their reliability both separately and in combination. The results will be discussed in a separate report.

The clinical data on 24 h survivors is shown in Table 3.

TABLE 3

Clinical Evaluation of 24 Hr. Survivors

	n	Total[1] Area	Max T_c	SGOT (IU/L) 24 Hr.	SGPT (IU/L) 24 Hr.	K (mEq/L) 24 Hr.
Experimental	39	56.2	42.0	12,597	5,278	5.5
		± 5.1	± 0.4	± 9,914	± 4,477	± 1.1
Control	11	54.3	42.3*	22,855*	11,624*	5.1
		± 5.5	± 0.4	± 11,292	± 6,137	± 0.4

[1]Core temperature was measured at 2 to 6 minute intervals and thermal area was calculated when core temperature exceeded 40.4°C using the formula thermal area (deg•min) ≈ξ time interval (2 to 6 min) x 1/2 (°C above 40.4°C at start of interval + °C above 40.4°C) at end of interval.

*$p < .05$ for student t test between the mean ± S.D. and the mean immediately above it.

The results indicate that the greater core temperatures of non-acclimatized control rats caused more substantial tissue damage as demonstrated by significantly higher elevations in serum transaminase activity.

In summary, these results suggest that artificial heat acclimatization induced by short, daily bouts of sub-lethal hyperthermia can produce an increased resistance to subsequent lethal heat exposures. In the future, research conducted under the prior work units 013 and 042 will be combined and reported as progress in work unit 042.

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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OB 6120	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	D. Change	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	009
b. CONTRIBUTING				
c. ~~XXXXXX~~	CARDS 114f			

11. TITLE (Precede with Security Classification Code)*

(U)Biological Processes that Limit Heavy Physical Work Ability of the Soldier (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	6	145
	CURRENT 80	7	168

19. RESPONSIBLE DOD ORGANIZATION

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* VOGEL, James A., Ph.D.

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SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: PATTON, John F., Ph.D.

NAME: DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Exercise Capacity; (U)Anaerobic Power, (U)Fatigue; (U)Military Performance; (U)Muscle Fibers, (U)Ergometry

23. TECHNICAL OBJECTIVE.* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The combat soldier often depends upon his ability to perform sustained and sometimes severe levels of muscular exertion. The objectives of this research are to a) identify and characterize those biological processes that influence his capacity to perform heavy work, thereby providing a rational basis for improving the soldier's performance; and b) identify the physiological and biochemical processes that occur during physical training both at the whole body and muscle level, thereby providing a rational basis for improving physical training programs.

24. (U) Specific areas of study will include: (1) environmental influences on physiological work capacity and performance, (2) affects of disease or other altered states of the body on exercise performance capacity, (3) development of measures and methods of training for anaerobic fitness, and (4) relationship of muscle histochemistry to muscular strength and endurance.

25. (U) 78 10 - 79 09 Aerobic fitness, muscle strength and muscular endurance were not consistently influenced by translocation across multiple time zones so as to influence work performance of infantry troops. An acute viral infection (sandfly fever) was found to impair muscular strength and voluntary submaximal walking endurance. A high intensity cycle ergometer has been built and calibrated to measure anaerobic capacity of both concentric exercise capacity.

*Available to contractors upon originator's approval.

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DD FORM 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 009 Biological Processes that Limit Heavy Physical Work Ability of the Soldier

Study Title: PH-5-78 Effect of Transatlantic Troop Deployment on Physical Work Capacity and Work Performance

Investigators: James A. Vogel, Ph.D., James B. Sampson, Ph.D., James E. Wright, CPT, MSC, Ph.D., Joseph J. Knapik, SP6, John F. Patton, Ph.D. and William L. Daniels, CPT, MSC, Ph.D.

Background:

Current threat analyses for the European Theater have led to U.S. military contingencies which call for rapid large scale troop deployment from CONUS to Germany. Such movements would not only entail the crossing of at least six time zones but would also include other potential stresses such as sleep and food deprivation, dehydration, noise, vibration and fear (1). It is therefore not surprising that during deployment training exercises such as "Reforger", commanders have observed apparent impaired performance and general malaise in troops upon arrival in Germany.

In July 1977, the Commanding General, US Army Europe (CG, USAREUR) requested information on whether the effect of rapid transatlantic deployment of troops would impair combat effectiveness. Information could be provided on mental and cognitive function but no information was available on the extent or severity of physical performance or what specific courses could be taken to ameliorate the supposed effects. On 6 March 1978 the CG, USAREUR requested of The Army Surgeon General: "_____ your assistance in further study of this critical combat readiness problem in order to define its scope and determine possible remedies". Consequently, this laboratory was tasked to study the effect of translocation on ability of infantry soldiers to perform heavy physical work.

The ability to carry out physically demanding tasks (work performance) is dependent both on the physiological capacity of the body as well as the person's willingness to work. Thus, to evaluate the possible effects of translocation on

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work performance, it was desirable to study both the physiological capacity and the behavioral components of work.

Physical work capacity may be defined as the body's capacity to generate energy for muscular activity. Three sources of energy exist: (a) chemically stored energy in the muscle in the form of creatinine phosphate (CP) and adenosine triphosphate (ATP); (b) ADP and CP generated from anaerobic metabolism of substrates and (c) ATP and CP from aerobic metabolism of substrates. Stored energy is limited and used only in brief muscular contractions. It can be assessed as maximal isometric or dynamic force (maximal voluntary contractions) and is commonly referred to as maximal muscular strength. Anaerobic energy capacity is predominantly used during short high intensity exercise and can be quantified in terms of muscular strength endurance (endurance time at some percent of maximal strength). Aerobic energy capacity is used for long term submaximal exercise. It is measured in terms of maximal oxygen transport to the muscles (maximal O_2 uptake).

The question of whether any of these energy generating systems could be affected by transmeridian movement is open to speculation. These energy systems are highly integrated and involve in part the cardiovascular system, central nervous system and endocrine systems. While some components may in fact be relatively unaffected by circadian cycles, we know that sympathetic and adrenal steroid activities are affected (16-18). It has been reported that aerobic power capacity changed with the 24 hour cycle (19), but in fact, only the heart rate changed which was used to predict aerobic power. There are no reports in the literature of directly measured aerobic power being altered during the circadian cycle. In contrast to aerobic power, anaerobic power and maximal strength involve extensive coordinated nervous system activity. The capacity to voluntarily exert maximal force (strength) and to maintain a normal pattern of maximal exertions over a period of time (strength endurance) requires a complex and highly coordinated pattern of excitation and inhibitation of muscle fibers. Thus, it may be postulated that muscle strength would be more susceptible to disruption of biorhythms from transmeridian flights than aerobic power capacity.

This study was designed to examine all three physiological work capacity components (strength, anaerobic and aerobic) as well as behavioral aspects and their integrated affect on task performance.

Progress:

This study utilized soldiers from a rifle company (Company B) and headquarters company of the 5th Battalion, 7th Brigade, 1st Cavalry Division that were being permanently transferred from Ft. Hood, TX to West Germany. Ninety-four soldiers volunteered for the study. Thirteen subjects (13.8%) were excluded from the study as a result of a medical examination, leaving 81 as the starting sample. These 81 subjects were then randomly assigned to three groups (red, green and yellow) for the purposes of testing.

The study employed a pre-post deployment test design. Subjects underwent five days of testing one week prior to deployment and again during the first 5 days upon arrival, as follows:

22 Sep 78	- Briefing and physical exams
25-29 Sep 78	- Baseline testing
11 Oct 78	- Movement of subjects to Germany
12 Oct 78	- First day of testing in Germany
16 Oct 78	- Last day of testing in Germany

The subjects departed Ft. Hood on a DC-8 chartered commercial air craft at 0200 hrs and arrived in Nuremberg at 2245 local Nuremberg time. Two intermediate stops were made in Philadelphia (1 hr) and Shannon, Ireland (1/2 hr). Total in-transit time was 14-3/4 hours, crossing 6 time zones. From Nuremberg, the subjects were moved by commercial bus to the test site, Wildflecken Training Center, arriving there at 0115 local time (12 Oct). They were billeted by 0300 hrs and awakened at 0600 hrs and reported for testing at 0730 hrs. Thus, 8-3/4 hrs intervened between flight touch-down and commencement of testing.

Testing was divided into four sections.

1. Behavioral
2. Work Task Performance
3. Muscle Strength and Endurance
4. Aerobic Power

Each subject was tested in one section only each day, in Sections 2, 3 and 4, according to the following schedule:

Day:	1	2	3	4	5
Group					
Red	A	P	S	A	P
Green	P	S	A	P	S
Yellow	S	A	P	S	A

A = aerobic power testing section

S = muscle strength testing section

P = Task performance testing section

Behavioral questionnaires were administered daily immediately prior to and after the exercise testing (see Methods Section).

Briefly, the measurements carried out included:

1. Behavioral
   a. Background survey form
   b. Environmental symptoms questionnaire
2. Task Performance
   a. Six meter rope climb
   b. 125 yard man-lift and carry
   c. 300 yard sprint
   d. 1.5 mile run
3. Physiological Capacity
   a. Muscular strength and endurance
      (1) Isometric maximal strength of arm-shoulder, leg extensors and trunk extensors.
      (2) Dynamic strength and muscular endurance of arm flexors and knee extensors.
   b. Aerobic power by treadmill maximal oxygen uptake.

Behavioral responses commonly reported for transatlantic travel were observed and confirmed in a majority of the subjects in this study: tiredness, sleepiness, weakness, headache and irritability. While most symptoms had disappeared or significantly diminished by the fifth day in Germany - tiredness, sleepiness and irritability still persisted at that time (Figure 1,2,3).

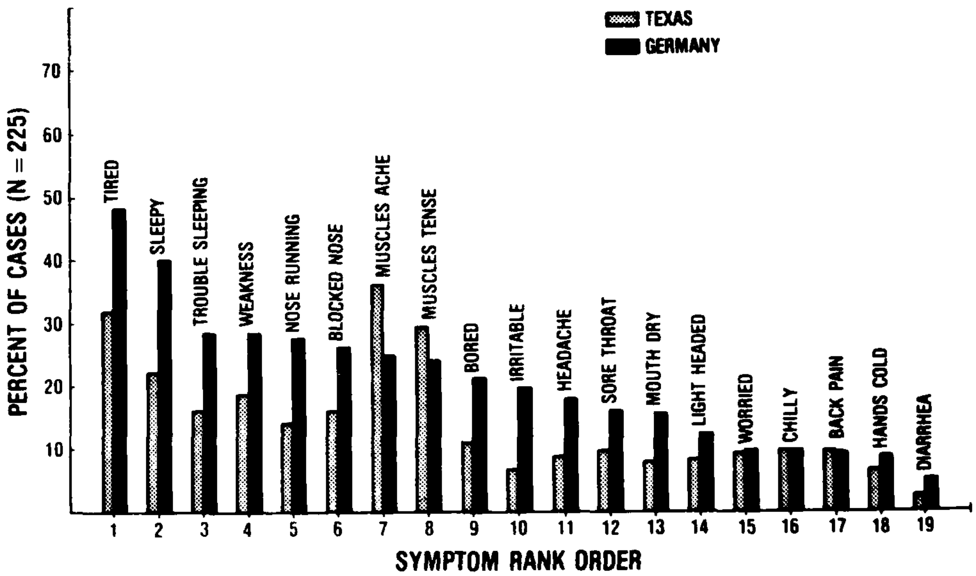

Figure 1. Rank order of symptoms based on percent reported during the five days in Germany

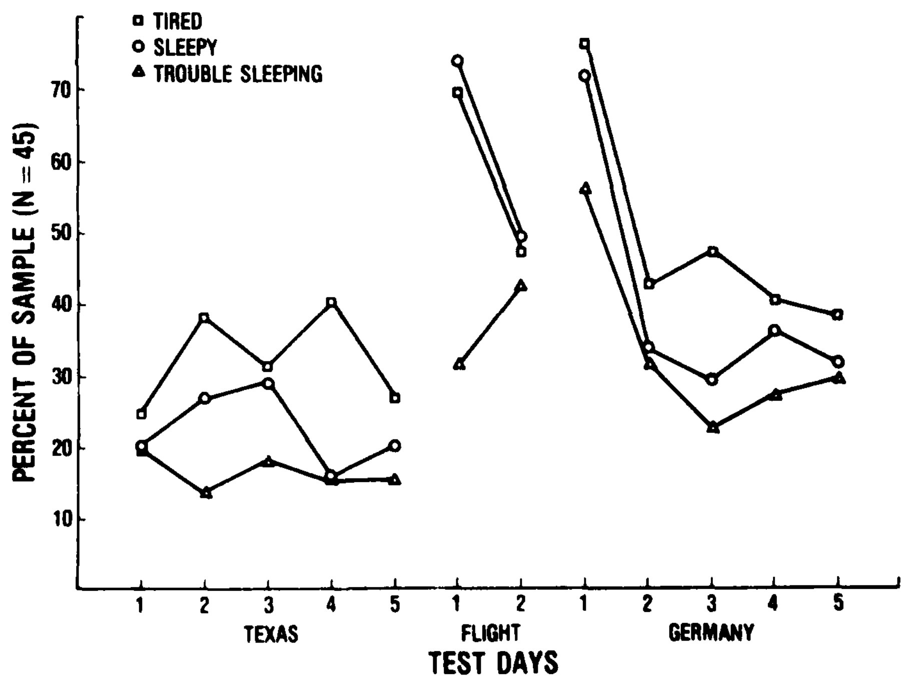

Figure 2. Percent of sample reporting Tired, Sleepy and Trouble Sleeping (N = 45)

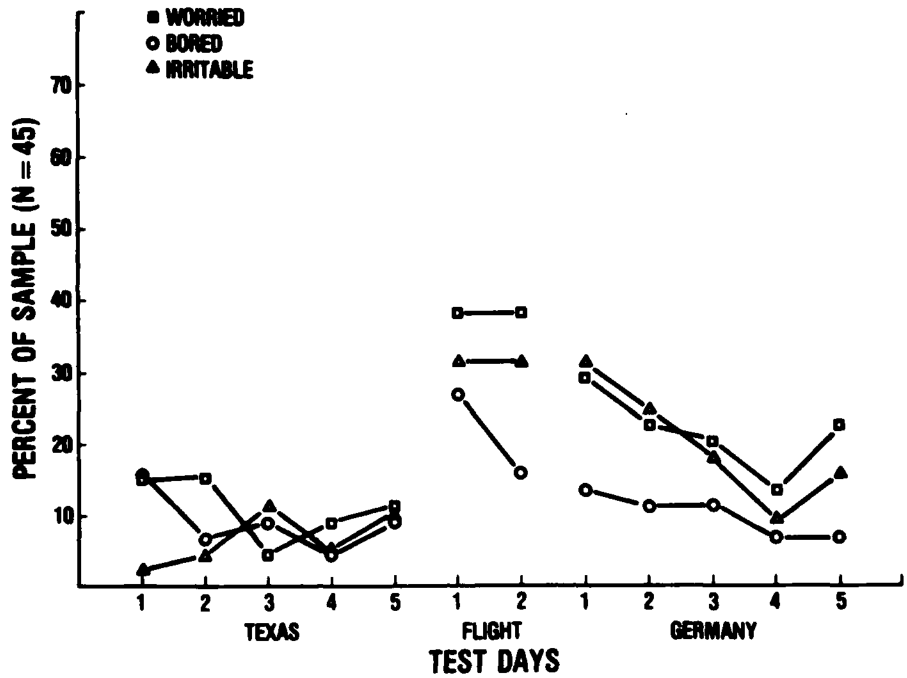

Figure 3. Percent of sample reporting Worried, Bored and Irritable (N = 45)

Performance of gross motor field tasks (rope climb, rush, lift and carry and run), which should reflect the culmination of both psychological and physiological affects on work ability, was essentially unaffected by translocation. Only one group (out of three) exhibited an isolated significant decrement in one event (rush). Thus, the work task performance suggested that, if present, psychological and physiological alterations were not of sufficient magnitude to alter work performance during the five days following translocation as assessed in this study.

The first aspect of physiological capacity measured, maximal static and dynamic strength, did exhibit some possible changes due to translocation. While static (isometric) strength of both upper body, leg and trunk were unchanged, with one exception, dynamic strength of arms was reduced after arrival in Germany in two out of three groups at slow contraction speeds (Figure 4) and in all groups at fast (180 degrees per second) speed (Figure 5). Dynamic leg strength appeared to be sufficiently confounded by the fatigue of repetitive testing to prevent any conclusions being drawn.

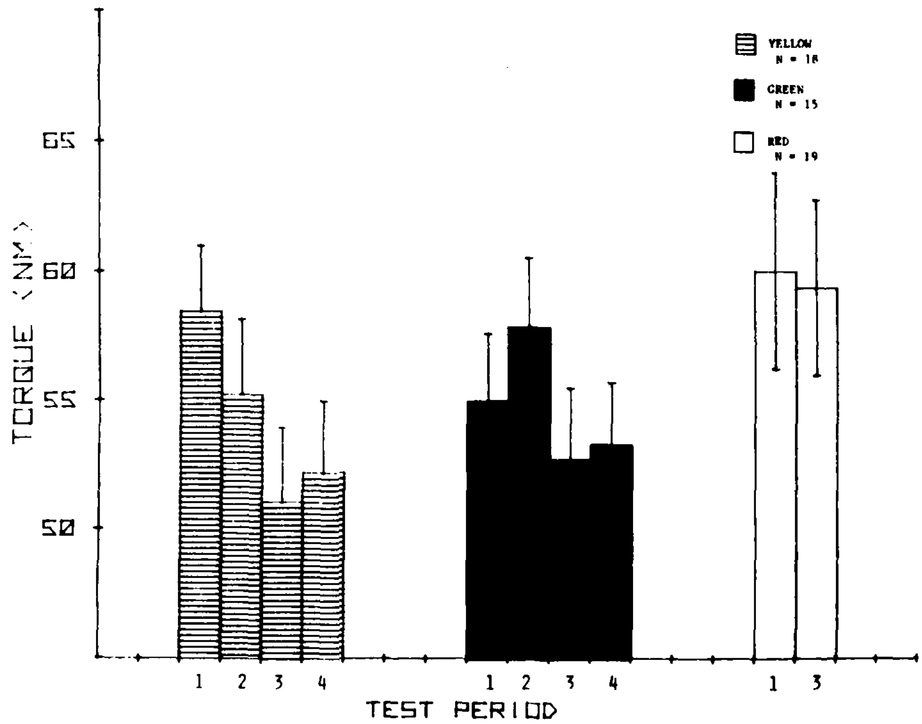

Figure 4. Dynamic are strength at 36 degrees/sec. Mean ± S.E.

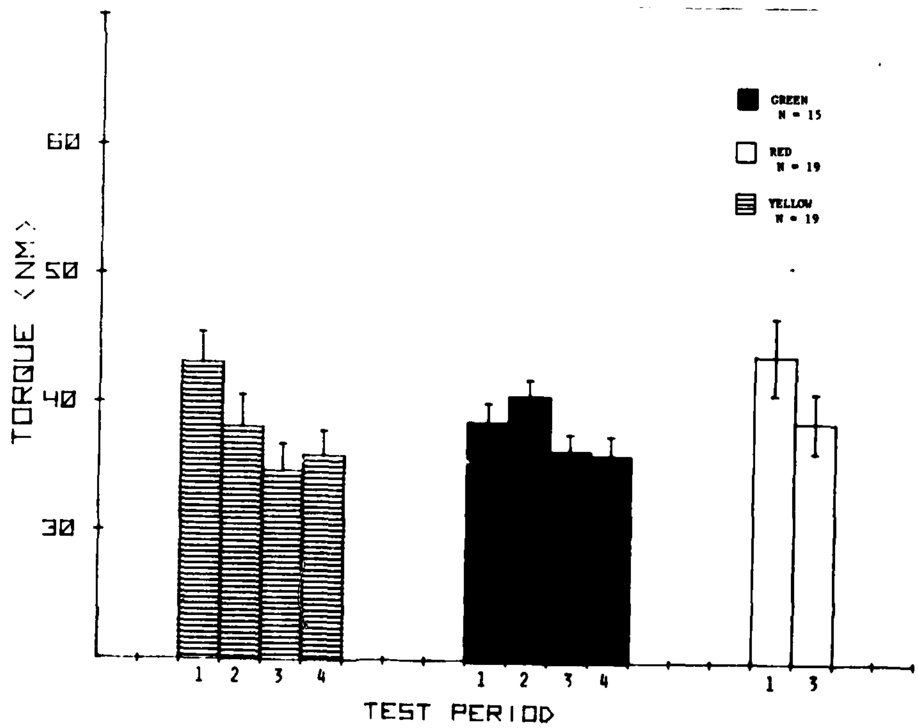

Figure 5. Dynamic arm strength at 180 degrees/sec. Mean ± S. E.

Measures of both arm (Figure 6) and leg muscular endurance, sustained repeated contractions for 60 seconds (anaerobic power), showed a significant decline in their force curve after arrival in Germany as opposed to Texas. The finding was generally consistent in all test groups, although fatigue from other testing may again have confounded the leg endurance findings.

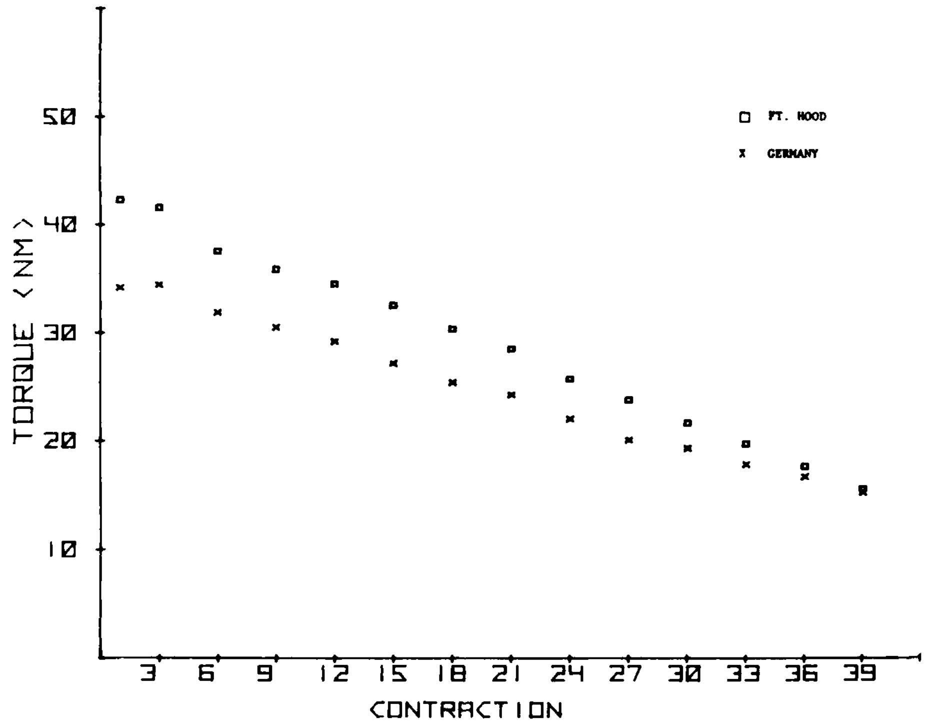

Figure 6. Dynamic arm endurance at 180 degrees per second for test groups combined

The last component of physiological capacity, aerobic power, as measured by maximal treadmill running was completely unaffected by translocation. Oxygen transport capacity and aerobic muscle metabolism for sustained whole body activity appears to be unaffected by the conditions experienced in this study.

It is impossible to resolve from the present study whether these observed alterations in muscular strength are due to the general stress resulting from translocation or due to one single component, such as biorhythm disruption or sleep loss. The stress of noise, vibration and fear often included in the description of translocation can be ruled out in this study since the movement

was made in commercial aircraft, by troops who for the most part previously deployed to Germany and were adequately prepared for this permanent change of station. Despite the comforts of commercial aircraft, sleep deprivation was nevertheless a prominent finding upon arrival in Germany and evident during the first days of testing. Halloway (15) has suggested that sleep loss is most likely a much more dominant stress than the rhythm disruption. No studies have been found which have examined the effects of sleep deprivation per se on muscle strength and endurance. Such a study appears indicated. Aerobic power during sleep deprivation has been studied in this laboratory (Gleser and Vogel, unpublished) without any discernable effects.

It is somewhat perplexing that decrements were found in muscular strength and endurance capacity without concomitant changes in task performance. Assuming that our measures of capacity in fact tested the same muscle groups that were employed in the task performance, one would then be led to conclude that the tasks were not performed to the point of taxing the maximal capacity of the physiological systems, or were inappropriate tasks for maximally taxing the physiological systems. If we can assume that the tasks selected sufficiently represent work performance required by the combat soldier, then we can only conclude that physiological capacity changes are not of sufficient magnitude to affect performance from a realistic or practical standpoint. The implications of the muscular strength and endurance decrements observed appear to be more of a theoretical than a practical nature.

Thus, in summary, the results of the study showed that along with the expected symptomatology, physiological work capacity was unaffected with the exception of dynamic arm strength and endurance. Despite these behavioral and isolated physiological changes, no significant decrement in work task performance could be documented with transatlantic deployment. Thus, it can be concluded that any decrements in willingness to work or physiological capacity were insufficient to become apparent in gross work ability as measured in this study.

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Vogel, J. A., J. B. Sampson, J. E. Wright, J. J. Knapik, J. F. Patton and W. L. Daniels. Effect of transatlantic troop deployment on physical work capacity and work performance. USARIEM Technical Report T 3/79, March 1979.

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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCE, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 009 Biological Processes that Limit Heavy Physical Work Ability of the Soldier

Study Title: Anaerobic Power Production as a Component of Physical Fitness

Investigators: Howard G. Knuttgen, Ph.D., John F. Patton, III, Ph.D. and James A. Vogel, Ph.D.

Background:

Numerous investigations have been published where humans engaged in such activities as leg cycling, arm cranking, walking, and running at sufficiently low intensities that most, if not all, of the energy production in the muscles was supported by aerobic metabolism. Relatively few studies of exercise involving anaerobic metabolism have thus far appeared, especially rhythmic exercise performed at very high intensities relative to the Maximal Voluntary Contraction (MVC) forces of the muscle involved. Concentric contraction exercise in human exercise performance is characterized as involving mostly shortening contractions of the active musculature, movement closer together of the skeletal parts to which the muscles are attached, and production of external work on an ergometer. The principal impediment to the study of a full range of intensities of rhythmic large muscle activity in humans has been the inavailability of ergometers that: a) provide resistances adequate to cover all exercise intensities of which a person is capable and b) possess the feature of power production so as to enable the study of exercise both with concentric and eccentric muscle contractions.

Ergometers presently available for the study of human performance in cycling or cranking can produce conditions of exercise involving repetitive contractions approximating up to 20-30% of the MVC of the muscle groups involved (as measured in the concentric condition). Because of the increased capacity of the same musculature to produce force under eccentric conditions, the intensity range of these ergometers relative to eccentric MVC is even more

limited. An ergometer was designed, therefore, to enable research involving exercise with both concentric and eccentric contractions at a full range of exercise, including the very highest intensities of which humans are capable under either condition.

Progress:

The ergometer designed and developed at this Institute for high intensity exercise has previously been described in detail (Annual Progress Report FY78; pp 133-137). For a concentric exercise experiment, the forward and decelerate modes on the control panel of the 5 HP motor are employed. The selector for speed/torque is set initially for speed and the control system maintains the motor (and pedal axle) at the speed indicated on the speed potentiometer. In this mode, the subject follows the pedals around passively at the established RPM with no attempt at active cycling.

The torque potentiometer would be set at the level of power eventually desired for concentric exercise. When the speed/torque switch is changed to torque mode, the control causes the motor to decelerate to 10% of the original speed (60 to 54 RPM). The subject is required to commence exercise and provide the amount of power necessary to maintain the original speed, e.g. 60 RPM.

For eccentric exercise, the reverse and accelerate modes are selected and the pedals are driven in the direction of the subject. When the change from speed to torque is made the control causes the motor to accelerate to 10% faster than initial speed (60 to 66 RPM). The subject resists the acceleration, maintains the initial speed and receives the power level preset on the torque potentiometer.

Experiments to provide both mechanical and biological calibration of the ergometer are in progress. For mechanical calibration in the reverse/accelerate mode (eccentric exercise), functional resistance was provided over the flywheel by a belt attached to electronic force transducers. A range of resistances (0-9 kg) was applied to the flywheel while the torque potentiometer setting was changed to maintain a pedal axle RPM of 60. A linear relationship was therefore established between the resistance applied and the torque setting. By knowing the flywheel circumference and the gear ratio of flywheel to pedal revolution, the resistance in kg was converted to a power term (kg.m/min or watts).

Mechanical calibration of the ergometer in the forward/decelerate mode (concentric exercise) can not be accomplished using the above technique because of the decrease in motor speed and pedal axle RPM when in the torque setting. At the present time, therefore, a calibration device is being developed that will permit the precise determination of exercise intensity for the subject by measurement of the amount of power investment by an external motor in the pedal axle to maintain RPM at a particular resistance setting on the ergometer.

Biological calibration is being provided by the comparison of physiological responses of human subjects on the new ergometer with data obtained from experiments performed with ergometers in common laboratory use. Figure 1 shows the oxygen uptake response for various torque settings for a subject undergoing both eccentric and concentric exercise. In exercise using eccentric muscular contractions, the conversion of torque to power can be made directly from the calibration curve previously described. The oxygen uptake responses for the various power levels agree with previously published data on eccentric exercise performed using other cycle ergometers.

For concentric exercise, Figure 1 shows that there is a considerable energy cost (approximately 1.7 l/min) when no resistance is being applied by the motor to the flywheel. This represents, therefore, the oxygen demands required to overcome the internal resistances of the motor. While this level of oxygen demand is produced by an exercise intensity of approximately 80-100 watts based on previous reports, a more accurate calibration awaits the development of the calibration device previously described for the forward decelerate mode of operation.

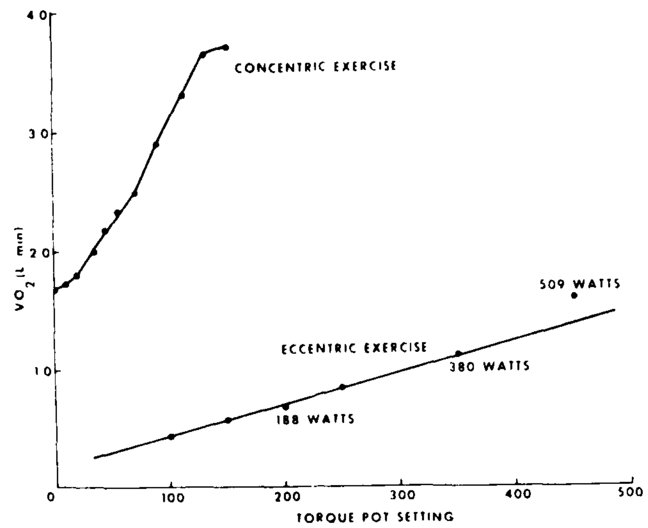

Figure 1. Oxygen uptake vs. torque potentiometer setting of exercise using both concentric and eccentric muscular contractions

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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 009 Biological Processes that Limit Heavy Physical Work Ability of the Soldier

Study Title: An Evaluation of Physical Performance Capabilities During Sandfly Fever Infection

Investigators: William L. Daniels, CPT, MSC, Ph.D., James E. Wright, CPT, MSC, Ph.D., James A. Vogel, Ph.D., Dan S. Sharp, CPT, MC, M.D. and Joseph J. Knapik, SP6

Background:

Sandfly (Phlebotomus or Papatasi) fever is a self-limiting febrile illness of viral etiology transmitted by biting insects of the genus Phlebotomus. Although the illness resulting from this disease is not serious clinically, its tendency toward explosive outbreaks in large groups of susceptible individuals after short periods of exposure makes it a potential hazard to military operations in certain parts of the world. The reason for its use in this study is that it is a well understood viral illness and is suitable for study as a model infection.

The disease is sudden in onset, self-limited, with no mortality or sequelae and a very predictable clinical course. It is characterized by frontal and retro-orbital headache, leukopenia, photophobia, generalized malaise, arthralgia and myalgia. Anorexia, nausea and vomiting may be associated with ill defined abdominal distress.

Previous studies have shown that static muscle strength and endurance is decreased in febrile infection (1). Other measures of performance have been recorded to be decreased in the early convalescence of patients suffering from various acute infectious diseases of about one week's duration (2,3,4).

The purpose of this study was to evaluate the ability of soldiers to perform physical work during the febrile period and early convalescence period of an infectious disease. The effect of the disease on parameters used to assess an individual's level of physical conditioning were also determined.

Progress:

In May of 1979, 9 subjects (7 experimentals, 2 controls) underwent a series of tests before, during and after an experimentally induced episode of sandfly fever. This study was performed at the request of and in collaboration with William R. Beisel, M.D., Scientific Director, USAMRIID and with other members of the USAMRIID staff. This report will primarily summarize data collected by USARIEM personnel. The experimental schedule for all subjects is outlined in Table 1.

TABLE 1

Experimental Schedule

Day of Week	Study Day	Procedure	
Friday	-7	Screening Physical	-
Monday	-4	AM Introduction of Procedures to Group A PM Sub-max Walking Group A	Group B Static & Dynamic
Tuesday	-3	Running $\dot{V}O_2$max on Group A	Group B Handgrip
Wednesday	-2	AM Introduction of Procedure to Group B PM Sub-max Walking Group B	Group A Static & Dynamic
Thursday	-1	Running $\dot{V}O_2$max on Group B	Group A Handgrip
Friday	0	Innoculation with Plasma or Saline 0800 hours	-
Sunday	2	Hospitalization 1200 hours	-
Monday	3	PM Sub-max Walking for Febrile S's	AM Static Dynamic & Handgrip on Febrile S's
Tuesday	4	PM Sub-max Walking for Remaining S's	AM Static Dynamic & Handgrip on Remaining S's
Thursday	6	AM Sub-max Walking for S's Febrile on Day 3. PM $\dot{V}O_2$max run	AM Static Dynamic Handgrip on S's Day 3
Friday	7	AM Sub-max Walking on Remaining S's	AM Static Dynamic & Handgrip on Remaining S's
		PM $\dot{V}O_2$ max run	
		Hospital Discharge 1600 hours	-

Test subjects were divided into two groups for initial testing. While one group performed the aerobic test procedures, the second group performed the muscle strength tests. The morning of days -4 and -2 served as an introductory period for the test subjects. During this time, they were familiarized with the tests that they were to undergo.

On the afternoon of days -4 and -2 subjects began testing. The aerobic portion consisted of three types of procedures:

1) resting measurements

2) submaximal walking

3) maximal oxygen uptake ($\dot{V}O_2$max) test

1. Resting measurements

At the beginning of each aerobic exercise session, subjects underwent resting measurements of heart rate (12 lead ECG), blood pressure and rectal temperature. In addition, all subjects performed a pulmonary function test as well as weight and skinfold measures for estimation of % body fat.

2. Submaximal walking

After the resting measurements, subjects began walking on a motor-driven treadmill at a speed of 3 mph and 0% grade. Every 3 minutes the grade was increased by 3% up to a maximum work load of 15% grade. During the last minute at each work load, heart rate, blood pressure, RPE, rectal temperature and oxygen consumption were measured.

3. Maximal oxygen uptake ($\dot{V}O_2$max) test

During the pre- and post-fever exercise session, the subject performed a $\dot{V}O_2$max determination. Initially, all subjects began running on the treadmill at a speed of 6 mph and 0% grade for 6 minutes. Following a 5-10 minute rest period, two to four additional runs were performed, each interrupted by a rest period. Work load was increased by adjusting speed and/or grade. During the last minute of each work load expired air was collected and analyzed. A plateau in oxygen consumption was defined as $\dot{V}O_2$max.

Muscle strength capacities were assessed by both static and dynamic strength and endurance tests.

4. Maximal static strength

Maximal static strength of three muscle groups were measured by a device designed in this lab (5). The muscle groups tested were: upper torso (arms and shoulders) and legs. Two 3-4 second maximal isometric contractions were

performed for each muscle group with a one minute rest between contractions. Forces were registered on electronic force transducers (BLD Model C2M1) and through digital transducer indicators (BLH Model 450A) were input displayed and recorded in a DECLAB 11/03 minicomputer which analyzed the force curves at 0.01/sec intervals.

Strength of the upper torso group was assessed with the subject securely fastened in a sitting position with a lap belt. The upper arms were positioned parallel to the floor with the elbows at a 90^{o} angle. The hands grasped an overhead bar that is attached by a cable to the force transducer.

Strength of the leg extensors was assessed with the subject seated as above with the knees bent at 90^{o}, the arch of the feet pushing against a bar attached by a cable to the transducer.

Isometric grip strength was measured with a handgrip ergometer which was adjusted for each subject so as to allow maximal grip output. Subjects exerted maximal grip strength for 3-5 seconds which was transferred through a turnbuckle to a force transducer and into the DECLAB 11/03 minicomputer.

Static handgrip strength endurance time at 40% maximal force was assessed prior to and following fever using the above apparatus. Heart rate (ECG) and cardiac stroke volume response were recorded. Stroke volume was measured by cardiac impendance (6), cardiac output was determined by multiplying heart rate x stroke volume.

5. Dynamic muscle strength

Maximal dynamic strength and power of the elbow-flexors and knee extensors was assessed utilizing isokinetic measuring equipment (Cybex Div., Lumex Corp., Bayshore, NY). For both the arm and leg measurements, the subject was seated and fastened by arm, leg and shoulder restraints into a heavy well-padded wooden chair which was in turn securely coupled to the isokinetic torque unit (Cybex II dynamometer). A separate apparatus was used to measure arm and leg capacities. Force exerted by the subject, measured as torque, was transferred from the dynamometer via an amplifier to a paper recorder and work integrator.

Muscle strength was assessed with two individual maximal contractions for each muscle group at each of two contractile velocities, 36 and 180 degrees per second. Endurance of the knee extensors was assessed over 50 consecutive maximal contractions at 180 degrees per second. Dynamic muscle endurance was evaluated before and after fever.

During the fever, 3 subjects were unable to finish the treadmill walk. Subject #4302 - felt dizzy at the end of 9% workload and the treadmill was stopped.

Subject #4307 - complained of shortness of breath, headache, and dizziness; treadmill stopped after 30 seconds at 12% grade.

Subject #4308 - stated that he could not complete test and stopped after 1.5 minutes at 9% grade.

Rectal temperature was significantly elevated ($p < 0.005$) at rest and at all exercise workloads during infection. However, the rate of the temperature rise was unaltered by the fever state. Resting heart rate during infection was significantly higher ($p < 0.01$) than in the pre- and post-fever state. The heart rate during fever at 0% grade was significantly higher ($p < 0.01$) than at post-fever. RPE was significantly ($p < 0.05$) higher than the pre-fever value at 0% and 6% grades during fever. The results of aerobic testing are summarized in Figures 1 and 2 and in Tables 2 and 3.

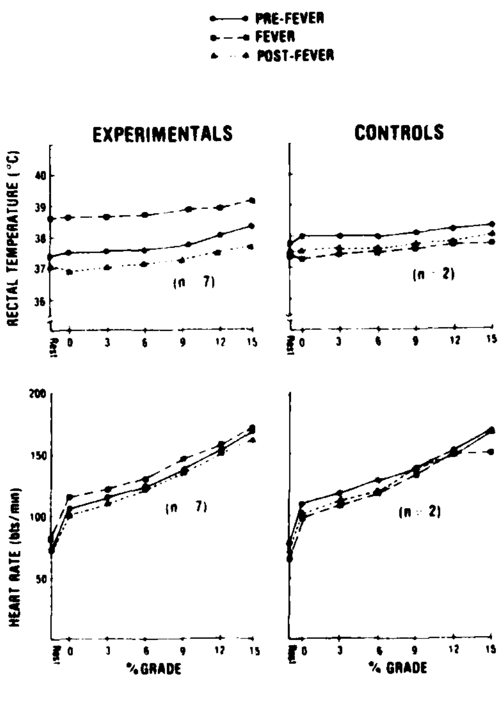

Figure 1. Response of Heart Rate and Rectal Temperature to Walking (3 mph) with a 3% Grade Increase Every 3 Minutes

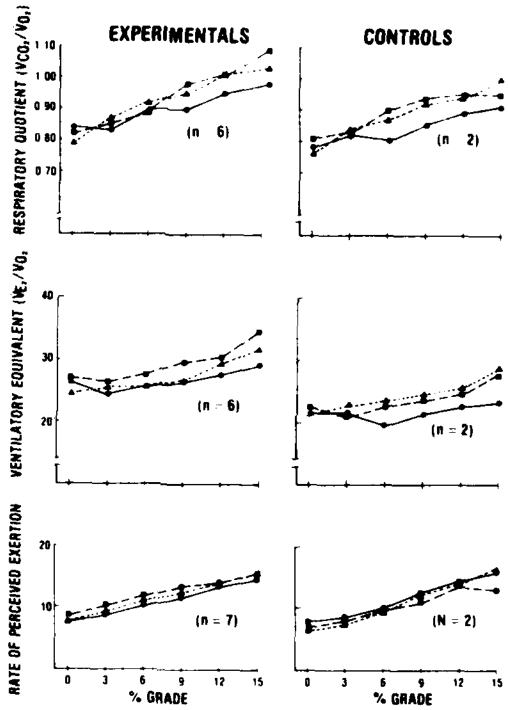

Figure 2. Respiratory Quotient, Ventilatory Equivalent and Perceived Exertion While Walking (3 mph) at Increasing Grade. See Legend of Figure 1.

TABLE 2

Minute Ventilation (BTPS) (l/min) While Walking at Increasing Grade Before, During and After Fever

	Pre-Fever	Fever	Post-Fever
		3 mph 0%	
Experimentals (n = 6)	30.13	30.82	27.18*
Controls (n = 2)	22.65	21.20	21.50
		3 mph 3%	
Experimentals	33.27	34.95	34.28
Controls	26.25	24.05	27.00
		3 mph 6%	
Experimentals	41.50	42.47	42.08
Controls	27.60	30.15	32.10
		3 mph 9%	
Experimentals	45.88	54.56*	51.70
Controls	34.10	37.90	41.13
		3 mph 12%	
Experimentals	59.77	68.37	64.98
Controls	44.10	46.90	49.86
		3 mph 15%	
Experimentals	57.80	85.67	84.47*
Controls	51.70	48.50(n=1)	64.60

*$p < 0.05$

TABLE 3

Oxygen Consumption (ml/kg.min) While Walking at Increasing Grade Before, During and After Fever

	Pre-Fever	Fever	Post-Fever
		3 mph 0%	
Experimentals (n = 6)	15.35	15.77	14.97
Controls (n = 2)	16.15	14.55	15.25
		3 mph 3%	
Experimentals	18.70	18.42	18.13
Controls	18.80	17.70	18.25
		3 mph 6%	
Experimentals	21.52	21.40	21.35
Controls	22.05	20.35	21.05
		3 mph 9%	
Experimentals	25.15	26.06	25.85
Controls	24.95	24.65	25.75
		3 mph 12%	
Experimentals	29.97	30.52	29.32
Controls	30.45	29.30	30.25
		3 mph 15%	
Experimentals	35.15	33.70	33.68
Controls	34.75	28.80(n=1)	34.40

Figures 3 and 4 illustrate the effect of inoculation on rectal temperature and poly morphonucleocytes. The viral infection also had a significant detrimental effect on muscle strength. Mean strength capacities (Figures 5 & 6) were reduced from 2 to 23% during fever. No relationships were apparent between either absolute or relative individual strength decrements and the peak fever temperature, fever duration, or the absolute initial strength capacity.

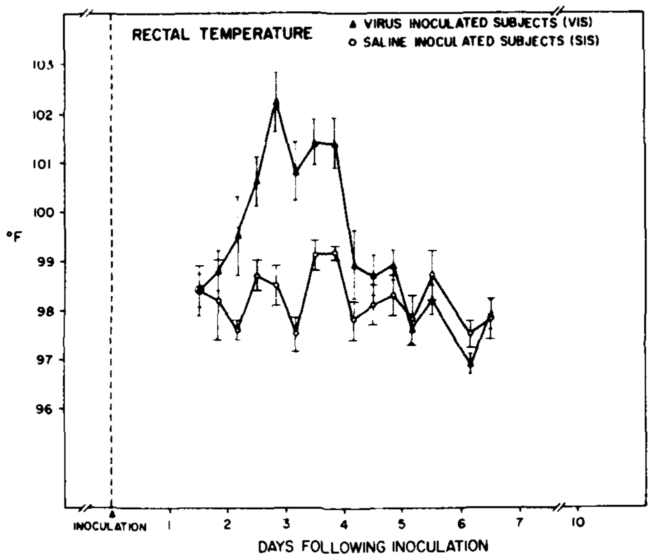

Figure 3. Rectal Temperatures after Inoculation

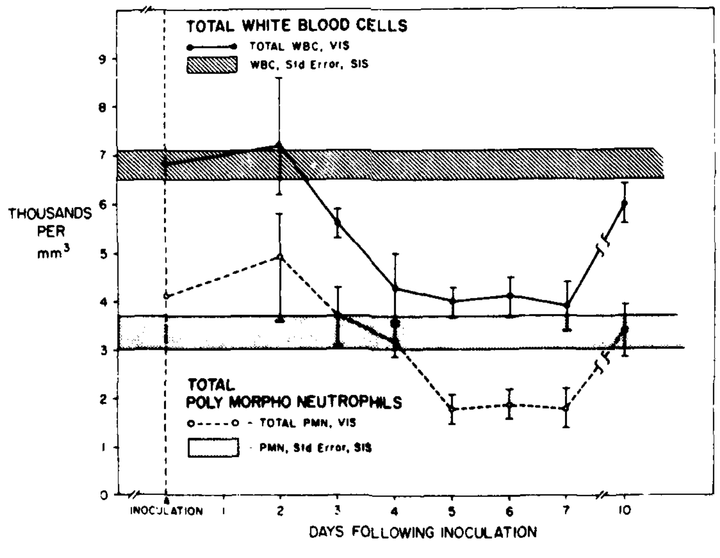

Figure 4. Total White Cell Counts and Polymorphoneutrophils after Inoculation

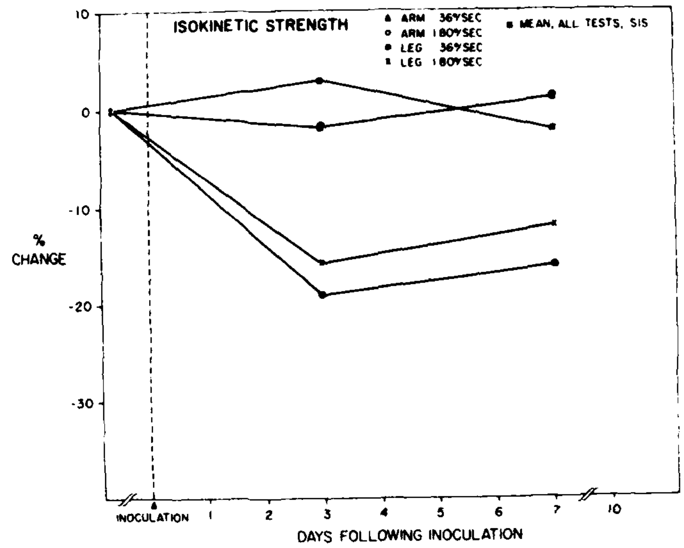

Figure 5. Isokinetic Strength Before, During and After Fever

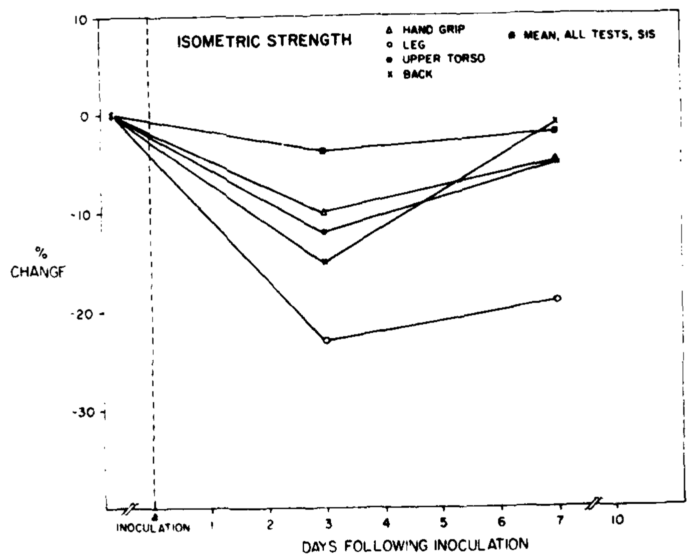

Figure 6. Isometric Strength Before, During and After Fever

The physiological response to walking was only minimally affected by fever. The most notable affect was the inability of three subjects to finish the work task. As with muscle strength, there did not appear to be any relation between level of fitness, degree of fever or fever hours and work performance. The severity of subjective symptoms associated with the fever was greatest in those subjects who could not complete the walk and had the largest decrements in muscle strength. There was no single parameter that we measured that was a good indicator of one's ability to perform. While we have demonstrated that performance is decrimented by viral infection, no clinical or physiological variable that was measured was a good indicator of performance.

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(82010)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OC 6133	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	D. Change	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	010
b. CONTRIBUTING				
c. ~~XXXXXX~~	CARDS 114f			

11. TITLE (Precede with Security Classification Code)* (U)Structural and Functional Alterations in Cells, Tissues and Organs Induced by Exposure to Environmental Extremes (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 012900 Physiology; 010100 Microbiology; 003500 Clinical Medicine; 005900 Environmental Biology; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
79 05	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	2	30
	CURRENT 80	7	222

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* BOWERS, Wilbert D., Ph.D.

TELEPHONE: 955-2862

SOCIAL SECURITY ACCOUNT NUMBER:

21. GENERAL USE

Foreign Intelligence Not Considered

ASSOCIATE INVESTIGATORS

NAME: HAMLET, Murray P., D.V.M.

NAME: DuBOSE, David A. DA

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Hypothermia; (U)Teticuloendothelial; (U)Heatstroke; (U)Tolerance; (U)Hepatic Necrosis; (U)Isolated; (U)Perfused Rat Liver; (U)Endotoxin

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The objectives of this research are to develop and utilize adequate subcellular, cellular, organ, and whole animal models to clarify the mechanisms of pathological changes produced by environmental extremes of cold, heat, altitude and changes associated with physical fitness training. These studies apply disciplines of pathology to devise methods of prevention, prognosis and amelioration.

24. (U) The relationships between presence of microbial endotoxin and/or bacteremia to severity of heat exposure will be studied in the rat heatstroke model using the limulus amoebocyte lysate test. The protective effect of endotoxin tolerance will be evaluated. The results may be applied to increasing man's resistance to the effects of heatstroke. Pathological changes in the liver are among the most consistent findings subsequent to heatstroke. The isolated perfused liver has proven to be a useful tool in determining the pathological effects of heat on this organ. The pathological effects of exposure to specified perfusing liquids at various temperatures will be monitored by enzyme leakage and light and electron microscopy. The value of hepatoprotective agents in ameliorating heat injury will be studied.

25. (U) 79 05 - 79 09 At an estimated average lethal heat dose of 62.7% the highest level of gram-negative microbial and/or endotoxin invasion has been noted. Above and below this dose the deggree of invasion was less. Invasion was found to be associated with shifts in the flora of the small intestine. When perfusion of isolated livers was terminated after specified intervals, centrilobular necrosis, indistinguishable from that observed in intact rats after heatstroke, was demonstrated by light microscopy after 75 min. at 43°C.

*Available to contractors upon originator's approval

Project Element:	6.11.02.A DEFENSE RESERACH SCIENCES, ARMY
Project:	3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	010 Structural and Functional Alterations in Cells, Tissues and Organs Induced by Exposure to Environmental Extremes
Study Title:	The Effects of Heat on the Structure and Function of the Perfused Rat Liver
Investigators:	Wilbert D. Bowers, Jr., Ph.D., Roger W. Hubbard, Ph.D., Murray P. Hamlet, D.V.M. and John T. Maher, Ph.D.

Background:

This work unit was initiated as part of a realignment of the Experimental Pathology Division's research program. It represents completion of research conducted under work unit 021 which was terminated.

Since most of the unstable and developing countries of the world lie within areas of relatively high average temperatures, the potential for exposure of troops to hot environments is prominent. Exposure of unacclimatized individuals to hot environments under stressing conditions could result in hyperthermia with devastating consequences.

Heatstroke, a severe consequence of hyperthermia, results in numerous alterations in biological processes. Noted among these is hepatic necrosis which has been demonstrated in both human heatstroke (1,2,3) and the rat model for heatstroke (4,5). Work in this laboratory has demonstrated that lesions produced in hyperthermic rats (4) are similar to those observed in humans (2,3). Similar lesions were also produced in isolated perfused livers where conditions were precisely controlled. The effects of 90 min exposure at temperatures from 37^{o} to 43^{o}C were determined previously in terms of bile production, enzyme leakage and light and electron microscopy. The same parameters were also evaluated at a single temperature for different time intervals to demonstrate time of structural changes. This report describes the electron microscopic structure resulting when perfusion was terminated at intervals from 15 to 90 min.

Progress:

Figure 1 shows ultrastructure of typical control livers perfused at 37^{o} for 90 min. After 15 min exposure to $43^{o}C$, necrosis of a few individual cells was observed (Fig. 2). After 30 min, most tissue retained normal ultrastructure with only focal necrosis (Fig. 3). Beyond 45 min exposure, the ultrastructural changes were widely distributed (Fig. 4,5) and even intact cells displayed small flocculent densities (Fig. 6). However, some livers were more resistant to heat than others. Individual cells within the same liver also showed a range of responses to a given heat load. When the responses of intact livers were compared, some appeared to be nearly normal while the groups response for the same heat load predicted severe injury. This may relate to the general metabolic state of the cells, or their anatomical positions. The presence of heat-resistant and heat-sensitive rats (6) or heat sensitive and heat resistant livers supports the theory that heat injury represents a continuum varying from mild or no injury to severe injury at given heat loads.

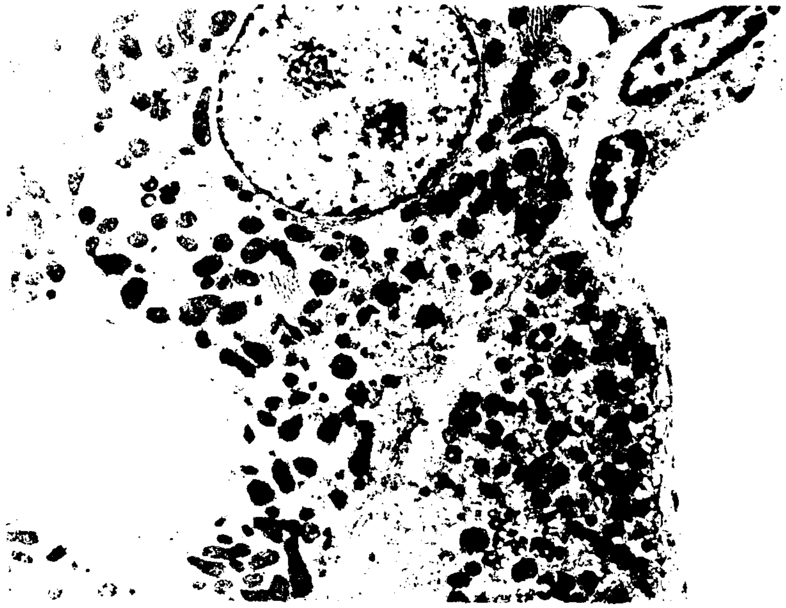

Figure 1. Control rat liver perfused at 37°C

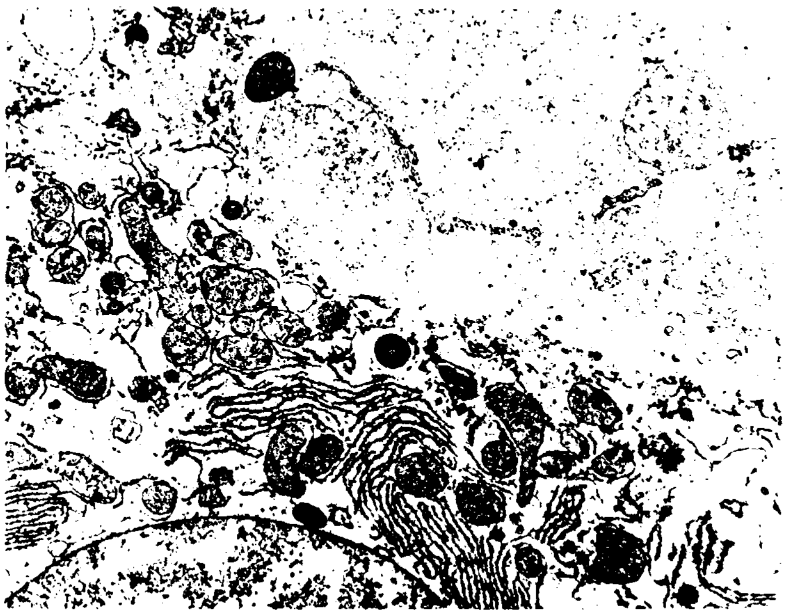

Figure 2. Rat liver perfused for 15 min at 43°C

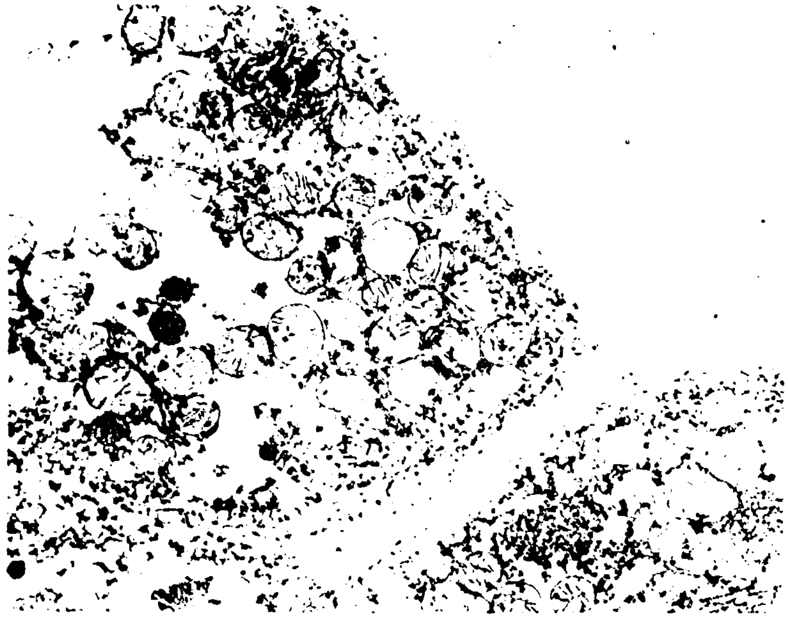

Figure 3. Rat liver perfused for 30 min at 43°C

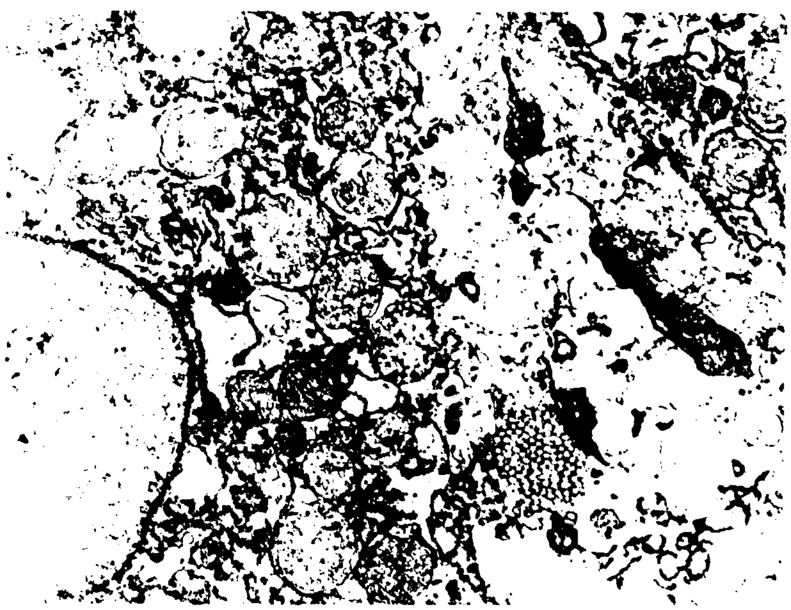

Figure 4. Rat liver perfused for 60 min at 43°C

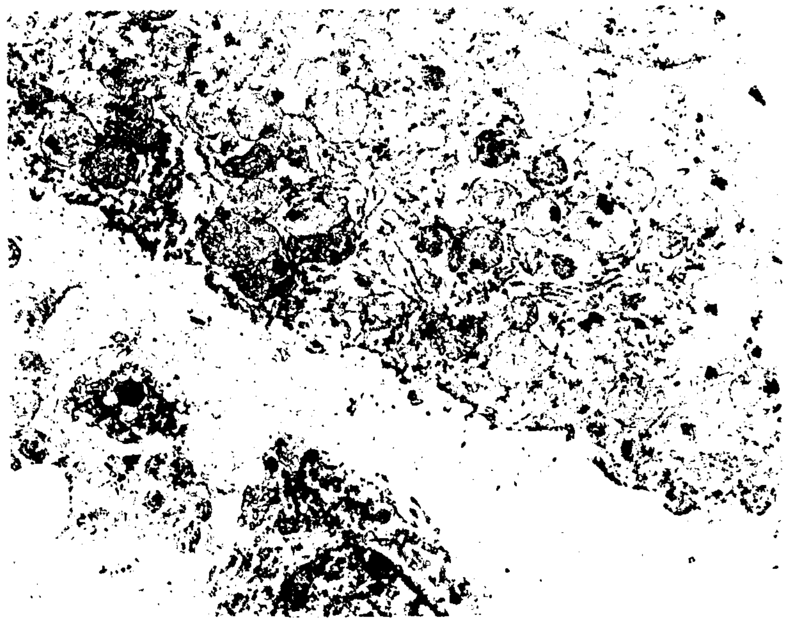

Figure 5. Rat liver perfused for 75 min at 43°C

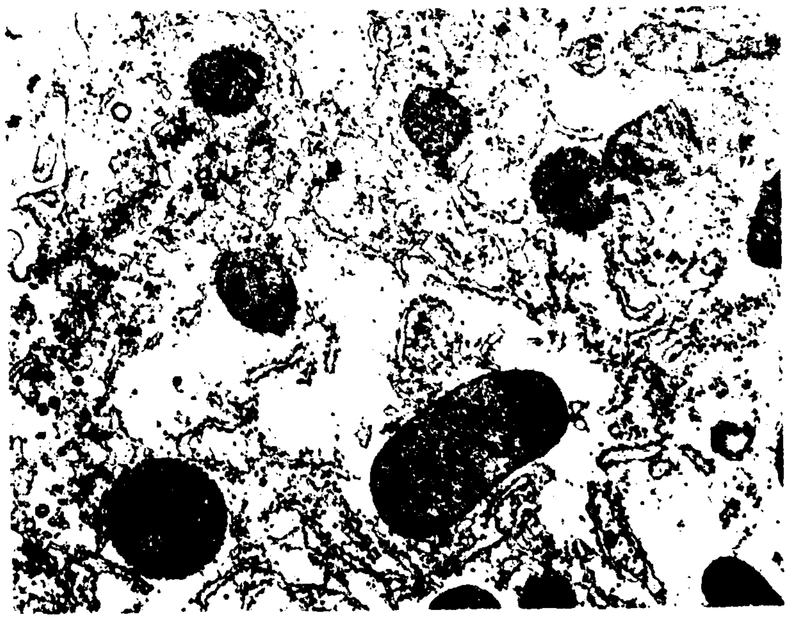

Figure 6. Rat liver perfused for 45 min at 43°C

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(82011)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
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3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	011
b. CONTRIBUTING				
c. XXXXXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)*

(U) Assessment of the Impact of the Environment on Military Performance (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 013400 Psychology; 005900 Environmental Biology; 002300 Biochemistry; 012900 Physiology Stress

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 11	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	5	214
	CURRENT 80	7	261

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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RESPONSIBLE INDIVIDUAL

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20. PERFORMING ORGANIZATION

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

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SOCIAL SECURITY ACCOUNT NUMBER

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21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Human Performance in Heat; (U)Human Performance in Cold; (U)Human Performance at Altitude; (U)Sustained Human Performance

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Operational planning, personnel selection and training, new equipment design and the computer simulations used in doctrine and force development all require data on how environmental conditions affect individual operator capabilities. This work unit assesses the psychological and psychophysiological disruption caused by thermal stress, hypoxia and physical and mental fatigue which can impair critical military performance before the soldier becomes an environmental casualty.

24. (U) Psychological tests, performance tasks abstracted from actual Army jobs, and training devices are used under controlled conditions in the field and laboratory to quantify decrements in perceptual, cognitive and psychomotor functions of special relevence to the military. Psychological inventories provide a basis for predicting individuals whose performance is especially susceptible to stress, while psychophysiological measures are used to examine mechanisms underlying the decrements.

25. (U) 78 10 - 79 09 Color discrimination on the Farnsworth-Munsell 100 Hue Test was found to be directly related to personality type, level of illumination, and repeated testing. These findings are relevent to target detection and map reading. Reports were published documenting environmental effects and marked individual differences in performance of a number of military tasks (including reception of radio messages, decoding, plotting targets on maps, using fire direction center equipment) during exposure tin simulated high altitude, hot-wet and hot-dry conditions. Methodological studies of the use of EEG in evaluating performance under environmental stress are underway. In 1st quarter FY 80, a study will compare the accuracy of distance judgments made on actual terrain with judgments by the same artillery observers made from projected slides of the same scene. This validation is necessary prior to use of projected-slide simulation tasks under environmental stress in this work unit, and is also relevent to the use of such devices by TRADOC for training artillery FO's.

*Available to contractors upon originator's approval

DD FORM 1498, 1 MAR 68 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 011 Assessment of the Impact of the Environment on Military Performance

Study Title: Development of Methodology for Analysis of Selected Cognitive and Perceptual Tasks by the Artillery Forward Observer

Investigators: John L. Kobrick, Ph.D. and Bernard J. Fine, Ph.D.

Background:

Forward observers (FOs) are essential to the use of artillery in direct support of troops in ground combat. The Human Engineering Laboratory's HELBAT I study (1969) established that 53% of the variance in accuracy of artillery observed fires were accounted for by the FO. Those findings were made under relatively favorable experimental conditions and involved primarily problems with the FO's location of himself and the target in relation to map coordinates and with estimated distance. Under full operational conditions, the FO must detect and identify targets and discriminate hostile from friendly forces. He must also preplan suitable targets to support the ground commander's plan of attack or defense, and serve as adviser to the commander regarding fire support resources. He must also communicate by radio in consise, often encoded, format with the fire direction center and fire support officer. The recent adoption of the Fire Support Team (FIST) concept has increased the effective number of artillery observers, and has placed the responsibility for the coordination of these geographically dispersed teams on the team's officer (usually a junior lieutenant). Consequently, more of the actual observation and adjustment of the artillery fire must be conducted by enlisted personnel.

Equipment currently under development adds new demands for psychomotor and cognitive abilities for which there is little field experience. The Ground Laser Locator Designator (GLLD), used to "illuminate" moving targets for destruction by homing bombs and artillery projectiles, demands very precise optical tracking performance by the FO operator. Individual differences in ability to master the GLLD are already leading to high dropout rates during training. Digital Message Devices, used to send calls for fire and other

information by radio in brief digital format, require memory of message format codes and pressing of small buttons under urgent environmental stess conditions. Tasks like these are often individual, forced-paced efforts which do not easily allow team double-checks. Like most FO tasks, they have important human factors aspects in common with tasks in other critical Army MOS's. The potential problems of selecting individuals to assign to these complicated tasks does not appear to be improving in the All Volunteer Army.

To the extent that many important FO task functions approach or exceed the performance limits of many people under relatively benign conditions, there is reason for concern that they may be susceptible to serious degradation by physiological stressors (heat, cold, hypoxia) and fatigue. There is a need for reasonable estimates of those degradation functions, based on empirical data, to incorporate into the computer simulation models which the Army currently uses to define requirements and specifications for new equipment developments, and to determine doctrine and force structures for their eventual employment. Understanding and prediction of individual differences in ability, especially under stress, is also needed to focus personnel selection and training to save time and money.

This work unit is concerned with identifying critical perceptual, cognitive or psychomotor skills in actual Army tasks, then developing or adapting performance tests from those tasks which retain face and content validity yet which can be studied in the laboratory or field under controlled environmental and experimental conditions. Standard psychological tests and physiological measurements are used concurrently to relate performance findings on these tasks to the scientific literature and to establish mechanisms for observed changes and individual differences.

Progress:

Discussion with personnel at the US Army Field Artillery Center and School (USAFACAS) and at the Human Engineering Laboratory identified a number of critical task elements in current or developmental weapons systems which may be vulnerable to environmental stress (including those used as examples in the Background section of this report and of those of two other studies within this work unit). At the Combat Developments Directorate,

USAFACAS, the com puter wargaming models used to generate Field Artillery input and solutions to the standard Training and Doctrine Command SCORES scenarios (1) are currently undergoing revision into modular format. As a result, it will soon be convenient to add algorithms to simulate degradation of FO performance due to environmental stress or fatigue.

The Training Developments Directorate, USAFACAS, is currently utilizing the prototypes of an Observed Fire Trainer (OFT) to train student forward observers in the classroom prior to having them adjust actual artillery rounds on the firing range. The OFT is similar in principle to the system which this USARIEM work unit proposed to develop in a simpler form as a performance evaluation test for environmental stress research (2). A computer-guided system projects a terrain scene on a screen and superimposes on it stationary or moving target images. The observer, equipped with a map of the same terrain, views the screen through binoculars and calls for artillery fire as he would on an actual battlefield; the system then projects the image of artillery bursts on the screen where they would have appeared on the terrain. The OFT at USAFACAS had been developed under contract but had failed its Operatinal Test because of reliability and maintenance problems. In FY 80, Training Developments Directorate will conduct tests of two competing British systems, one of which has been purchased by the UK Royal Artillery School. The US Army will probably select one of the two British systems for issue throughout the active Army, National Guard and Reserves. USARIEM has therefore deferred further development of a simulation device for laboratory research pending the outcome of the USAFACAS tests. It may be feasible to take over the prototype OFTs now at USAFACAS when they are replaced, or better, to use the system which will become standard for training throughout the Army for USARIEM's environmental stress research. These devices have the advantages of portability, versatility, and the capability of simulating subtle and complex details of artillery technique; it remains to be determined whether the stimuli can be presented with the degree of precision required for psychological and psychophysiological research.

Studies of selected aspects of the FO's visual tasks are meanwhile continuing. Studies of color discrimination ability and of distance estimation are reported separately under this work unit. A study of target detection as a function of viewing distance (target size) and level of illumination which was

conducted as part of a larger study at Pikes Peak (14,000 ft altitude) is reported under WU 051. Literature review and exploratory measurements of electroencephalographic parameters used by other laboratories as indices of attention and arousal have led to establishment of a new ILIR work unit concerned with development and pilot testing of psychophysiologic measures. Data analysis has continued on earlier studies, culminating in presentations and publication.

Presentations:

1. Basamania, C. Effects of prolonged exposure to high altitude on performance of a compensatory tracking task. Eastern Psychological Association Annual Meeting, Philadelphia, PA, 18 April 1979.

2. Fine, B. J. and J. L. Kobrick. The fallacy of the average person. Army Science Conference, West Point, NY 1979.

3. Kobrick, J. L. Effects of target size, peripheral position and viewing distance on visual target detection. Eastern Psychological Association Annual Meeting, Philadelphia, PA, 18 April 1979.

Publication:

Fine, B. J. and J. L. Kobrick. The fallacy of the average person. Proceedings of the Army Science Conference, 1979.

LITERATURE CITED

1. Scenario Oriented Recurring Evaluation System (SCORES); US Army Combined Arms Center, Training and Doctrine Command, Ft. Leavenworth, KA.

2. Annual Progress Report, Fiscal Year 1978. US Army Research Institute of Environmental Medicine, Natick, MA.

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 011 Assessment of the Impact of the Environment on Military Performance

Study Title: The Effect of Repeated Measures and Reduced Illumination on Performance of the Farnsworth-Munsell 100 Hue Test

Investigators: Bernard J. Fine, Ph.D. and John L. Kobrick, Ph.D.

Background:

The ability to distinguish between subtle shades of color is a sensitive and highly quantifiable test of perceptual and brain function which has direct relevance in many activities performed by Army personnel. One problem for Army observers in the field is to distinguish camouflaged objects, which are concealed basically by reduction of their outlines and contrast by manipulation of shades of color. Interpreting terrain maps also requires sensitive distinctions between the shades of pastels which are used to designate important information on trafficability, cover and concealment, or altitude. Map contour lines are printed in tan and brown, rather than black, which may result in reduced functional legibility at low light levels, when tactical operations are likely to occur. These discriminations may have to be performed in adverse environments (whether ambient or inside a vehicle, tent or chemical protective clothing) involving hypoxia, cold or heat stress. Yet, for example, the specific task of determining the altitude of a plotted grid coordinate on these maps may be required under extreme time pressure and be the critical, rate-limiting step for an entire weapons system, e.g. for artillery counterbattery fire directed by the new Fire Finder radars.

Other DA agencies are concerned with the development and testing of camouflage patterns, maps, etc; however, those agencies need input regarding human capabilities and limitations. Selective sensitivity and dark adaptation for hues is well understood yellow (530 mu) is most visible at bright to moderate illumination, and hue sensitivity shifts toward the blue wave lengths of the visible spectrum as illumination is reduced. However, there is very little information on effects of environmental stressors on color sensitivity, especially

across a range of ambient illumination. At USARIEM, Kobrick (1) showed reduced color sensitivity zones in the field during hypoxic exposure. Others have demonstrated reductions in color saturation thresholds (2), and the reductions in color sensation threshold (3), due also to hypoxia. Possible effects of heat, cold and sustained physical work, with the physiological and psychological disruptions those produce, have not been explored. Furthermore, the interaction of stress with known individual differences in color discrimination ability (distinct from the well-known types of color blindness) also deserves further study.

The Farnsworth-Munsell 100-Hue Test (4) is one of the most widely used tests of color vision. It was designed to separate persons of normal color vision into classes of superior, average and low color discrimination ability and to measure zones of color confusion of color defective persons. The test is widely used as a color standard in color control laboratories by manufacturers of dyes, plastics, textiles and paints and to test personnel for various jobs requiring precise color judgment. It also is used clinically to aid in diagnosis of defective color vision, to monitor the progress of certain medical treatments which can affect color vision and to test for side effects of drugs. The military services use the test at times for screening of personnel for various jobs requiring color response.

According to the instructions, the test typically is administered once, although it may be given twice for purposes of reliability. In clinical applications, however, it is sometimes necessary to administer the test repeatedly, as when monitoring a patient's progress with medication known to affect color vision over time. With this type of sensory measure, particularly in situations where the respondents are not informed whether their responses are correct or incorrect there has been little reason to suspect that a person's performance might change substantially over repeated trials.

However, Fine and Kobrick (5) administered the test ten times to a number of soldiers in an environmental stress study, in order to assess the effects of heat and altitude on color discrimination, and found a very substantial improvement in performance over the first five of six trials which were conducted under non-stressful conditions. In addition, they found that the improvement over the first four trials was due primarily to field-independent subjects. This result was consistent with that obtained in an earlier study by Fine (6) who found extremely large differences in color discrimination ability between subjects selected as

extreme on the dimension of field-dependence-independence (7). Field-dependence-independence is a personality dimension reflecting an individual's ability to perform perceptual tasks requiring abstract thinking. In Fine's study, the test was administered only twice, but improvement was noted from first to second administration and was substantially accounted for by the field-independent subjects.

This apparent learning effect and its interaction with field-dependence have important implications for any application of the test requiring repeated administrations. In experiments on the effects of stress on color discrimination ability, the stress effects may be negated by continued learning (improvement) of the subjects with each administration of the test. The interaction between learning and field-dependence may introduce certain biases into the results. In clinical applications, the effectiveness of the test in monitoring changes in color vision over extended periods of time may be questionable, unless the test is given a sufficient number of times before treatment so that the patient can reach an asymptotic level of baseline performance.

In addition to the learning aspects, the study described below focused on the effect of reduced illumination on color discrimination. This is an essential pre-test area for planned studies of stress-induced changes in color discrimination-related performance, e.g., map reading and target detection-identification, under varying degrees of illumination (dawn, mid-day, dusk). It is of great importance to determine beforehand the degree to which color discrimination and learning are affected by known decreases in illumination.

Progress:

Twenty volunteer military enlisted subjects stationed at Fort Devens, MA were each tested on the Farnsworth-Munsell 100-Hue Test twice daily (with a five-minute rest between trials) for five successive days. Seven trials (numbers 1 through 5, 8 and 10) were performed under illumination approximating mid-day (100 watts). Trials 6, 7 and 9 involved decreased illumination approximating dawn or dusk (25, 40 and 60 watts), the order of presentation being randomized across subjects. Illumination was supplied through a Macbeth Easel Lamp (ADE-10) and a Corning Daylight Roundel Filter. The following psychological instruments were also administered: 1) the Hidden Shapes Test (8) to assess

Introversion-Extroversion; 3) a personal history questionnaire. Because only two of the Fort Devens subjects scored as Field-Independent, an additional 16 volunteers were recruited at USARIEM and underwent the same testing to bring the total number of subjects to 36.

Statistical analysis is now underway. Preliminary results indicate that the previous finding of a relationship between field-dependence and color discrimination is strongly supported. (Figure 1). Field-independent persons were very much better at color discrimination than were field-dependent persons. A marked learning effect was demonstrated over repeated presentations of the test for all subgroups. Significant differences between high and low illumination conditions were found. Data analyses of complex relationships, e.g. the interaction of Field Dependence-Independence with Introversion-Extroversion, is continuing.

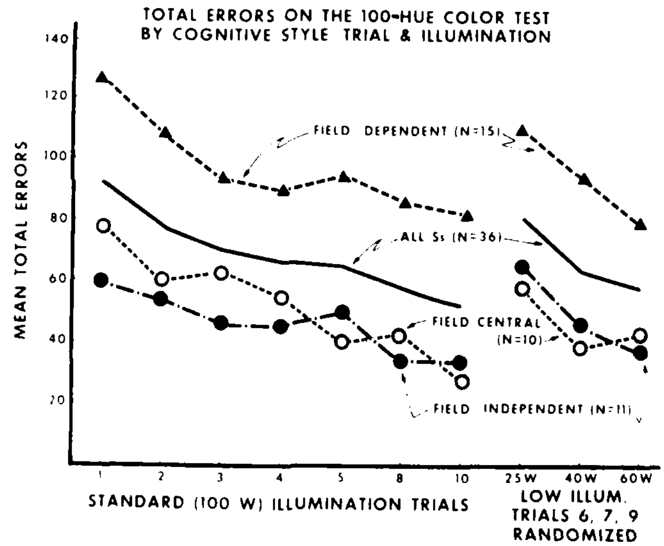

Figure 1. Errors on the Farnswell-Munsell 100-Hue Color Test are shown as group means per trial for three sub-sets of the total test subject population (N=36). Field dependent subjects (N=15) are shown by solid triangles, field-central subjects (N=10) by open circles, and field-independent subjects (N=11) by closed circles. Trials 1 through 5, 8 and 10 were conducted under bright illumination. Three levels of reduced illumination were used (in random sequence across subjects) during trials 6, 7 and 9.

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Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 011 Assessment of the Impact of the Environment on Military Performance

Study Title: Comparison of Distance Estimation Accuracy Between Real-World Scenes and Color Slide Representations of Them

Investigators: John L. Kobrick, Ph.D. and Bernard J. Fine, Ph.D.

Background:

That extreme natural environments (desert, mountain, tundra, forest or jungle) effect visual distance estimation is well known, but the causes of the degradation are complex and perhaps not fully understood. External factors influencing this skill undoubtedly can include light wave distortion (mirage), glare or gloom, unfamiliar vertical perspectives, absence of distinct reference points or their concealment by sand, dust, fog or snow, etc. These factors may be further complicated by protective clothing or equipment which limits the visual field. Finally, there is anecdotal reason to suspect that the physiological and psychological hazards of these harsh climates -- eye irritation, distraction by discomfort or fear, fatigue from exceptional physical exertion, hypo- or hyper-thermia, dehydration (with or without thirst), hyperventilation, hypoxia at high elevations, etc. can contribute to disorientation in relation to the terrain, and to error in the complex cognitive task of estimating distance by sight alone.

Recent studies and articles (1) have drawn attention to serious deficiencies in the ability of many Army personnel to orient themselves by use of maps and to navigate across country even under comfortable conditions. Many subjects seem to lack (or experience and recent training have failed to develop) the ability to estimate distances accurately by sight, a skill which, supplemented by a compass, enables one to determine one's location in relation to landmarks portrayed on the map. The problem is especially serious for personnel assigned as artillery forward observers (FOs), as they must not only know their own position at all times but must also estimate accurately the map coordinates of distant targets in relation to landmarks and adjust successive artillery shells onto

the target based on how far from it each shell bursts. Inaccurate distance estimation was judged to be a major source of FO error in the HELBAT I study, which attibuted 53% of the error in artillery observed fires to the FO. Marked individual differences in ability to learn these skills have also been noted.

The hand-held laser range finder (GVS-5) was developed specifically to replace gross human range estimates with precise measurements. Under optimal conditions these devices provide excellent results. Paradoxically, however, the laser range finders have generated a new need for human range estimation because they give spurious readings due to blowing smoke, dust or sparse vegetation on the line of sight between observer and target. The user must therefore be trained to disregard inappropriate values or, in newer models, to set limits for a "range gate" on the device. Laser range-finders are also adversely effected by bad weather. Finally, at best, only a small percentage of Army personnel, even of those who will be required to call for artillery fires, will be equipped with laser range-finders. Visual range estimation will remain an essential general skill.

To improve training of cross-country "orienteering" and distance estimation, it has been suggested that all Army posts should develop calibrated outdoor courses or ranges on which personnel would practice frequently. Improved classroom training is also being investigated, including the use of projected slides of terrain scenes with the associated maps (Map Interpretation Terrain Analysis Course, or MITAC). Even greater monetary savings can be achieved by training artillery observers indoors at target detection, calling for artillery fire and making subsequent adjustments using slide-projected terrain scenes on which can be superimposed computor-controlled images of targets and artillery bursts (with sound effects). Several such artillery observed-fire trainers are now commercially available and are being evaluated by the US Army Field Artillery Center and School. Sufficient transfer of training may take place between these simulations and either map terrain navigation or artillery adjustment for such slide technologies to be cost-effective even though the relationship to real-world visual function might be imperfect. Use of projected slides would also be economical in the laboratory to study the relevent perceptual, cognitive and psychomotor abilities under precisely varied environmental conditions; however, the use of such technology as a scientific tool requires that the relationship be specified. Accordingly, a study was undertaken at USARIEM to validate the use of projected slide imagery in measuring distance estimation ability.

Progress:

A protocol was prepared and approved for a definitive study of distance estimation to compare the accuracy of judgments made from projected slides with judgments made, by the same observers, from the identical scenes in the real world. The study will use subjects with different levels of experience in distance judgment, ranging from trained forward observers to untrained recruits. The task will consist of judging the apparent distance of a familiar target object (2-1/2 ton truck) at various locations along a straight line of sight through the center of the observer's visual field of view. Twenty equally spaced target locations will be used, ranging from a near location of 600 meters to the farthest location available (approximately 1550 meters). The order of occurrence of the target distances will be randomized, and the same order will be used for all observers. The observers will be told only to judge how far away each target appears to be, based on their own personal criteria.

Photographs of each target location will be obtained at the time the observers are making their judgments. The cameras will be placed at the approximate eye-height of the observers. Standard reference slides will be taken, using surveying equipment, in order to calibrate the slides for correct size of the target object during projection.

Approximately two weeks after the field trials, the same observers will be tested in the laboratory using the color slides made from the photographs obtained at the actual time of viewing. The slides will be presented so that the scene fills the visual field and the targets for each location are the same visual image size that they were in the field. The targets will be presented in the same order as they occurred in the field. In order to minimize and check on observers recalling their judgments, slides of the same target vehicle stationed at different distances in a different scenic background will be interspersed throughout the experimental slides. A comparison of the distance judgments for these slides with the experimental slides will provide a partial check on whether observers have memorized their field judgments.

Preparations for the study were completed in the fourth quarter of FY 79. A target estimation range was installed on a long flat grassy area adjacent to the main runway at Moore Army Air Field, Ft. Devens, MA. In conjunction with this, a close working relationship was established with the Directorate of Plans,

Security and Training at Ft. Devens. Through this relationship, support equipment and services were obtained which included a target vehicle (2-1/2 ton truck) driver and communications gear.

Liaison was established with the Field Artillery Assistance team (BAT) Army Regional Readiness Group, Ft. Devens and support was provided in the form of experienced artillery personnel to act as test subjects. Non-expert subjects were obtained from the NARADCOM test subject pool. Data collection for the field judgment phase is scheduled for October 1979 and the laboratory judgment phase in November-December.

LITERATURE CITED

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(82012)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OG 6149	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	H. Terminated	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	012
b. CONTRIBUTING				
c. ~~XXXXXX~~	CARDS 114f			

11. TITLE (Precede with Security Classification Code)*

(U) Assessment of the Impact of Environmental Stressors on Systemic Hypotension (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology; 012600 Pharmacology; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	2	1
	CURRENT		

19. RESPONSIBLE DOD ORGANIZATION

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21. GENERAL USE

Foreign Intelligence Not Considered

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SOCIAL SECURITY ACCOUNT NUMBER:

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22. KEYWORDS (Precede EACH with Security Classification Code) (U)Altitude; (U)Hypoxia; (U)Heat; (U)Cold; (U)Disabilities; (U)Systemic Hypotension; (U)Treatment; (U)Hypothermia

23. TECHNICAL OBJECTIVE.* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The phase of systemic hypotension (shock) which receives the most investigative effort is the normovolemic period following volume replacement. If preceded by sufficient stress during the hypotensive phase the normovolemic phase progresses to "irreversible shock" and death. Current military concepts limit the initial stress to primary wound trauma. The degree to which environmental stressors (altitude, cold, heat) interact with traumatic injury and induce or accelerate irreversible shock has not been explored. Trauma of a usual non-fatal nature may precipitate systemic hypotension given the environmental stressors under which combat troops fight and are evacuated. The purpose of this work unit is to expand our knowledge of the interaction of environmental stressors on the development and progression of shock.

24. (U) A hemorrhagic model of systemic hypotension will be developed and standardized in an animal model which will permit an investigation of the multitude of factors associated with "shock." The environmental stressors of altitude, cold, and heat will be applied to the animal model prior to and/or during hemorrhagic shock to determine their impact on the post-normovolemic phase. The information will be used in developing guidance for the prevention and treatment of shock in harsh environments.

25. (U) 78 10 - 79 09 Investigation into use of the pig as a hypovolemic model revealed it to be a better model than the dog. Although anesthesia and monitoring procedures are somewhat more difficult the response to medication and temperature regulation more closely resembles man's response. The lack of a senior investigator precludes continuation of this work. This work unit is now terminated.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.11.01.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 012 Assessment of the Impact of Environmental Stressors on Systemic Hypotension

Study Title: The Effects of Systemic Hypotension and Hypothermia on the Cardiorespiratory Functions of the Swine

Investigators: Donald E. Roberts, Ph.D. and Murray P. Hamlet, D.V.M.

Background:

Systemic hypotension (shock), whether hemorrhagic or neurogenic, is not an uncommon complication of combat or peacetime trauma. If promptly diagnosed and properly treated, the individual may be treated and returned to activity. If not treated, the individual may progress to a chronic hospitalization and/or death. Systemic hypotension may be complicated by existing environmental factors. High altitude operations place an individual in an hypoxic environment which may complicate the medical status of an individual with systemic hypotension. The peripheral vasodilation which accompanies the responses to a hot environment would be in opposition to the peripheral vasoconstriction necessary for the body's response to systemic hypotension. However, in cold environments, peripheral vasoconstriction may be potentiated by that which occurs as a result of shock and result in an increase in peripheral tissue cold injury. Also, decreased blood volume resulting from hemorrhage may result in an increased rate and depth of hypothermia. Initial efforts have been directed toward developing an appropriate animal shock model in which the effort of cold on the response to shock can be determined.

Progress:

Although the dog has been used extensively for hypovolemic shock work in the past, some significant problems exist in adding cold and heat as secondary stressors. A literature search reveals that the pig better mimics man's response to heat by fluid and electrolyte shifts and sweating and to cold by CIVD and

shivering. Although monitoring and anesthesia procedures are somewhat more difficult, it is felt the pig would be a better model for hypovolemic shock complicated by heat or cold.

(82013)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
DA OB 6143	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
78 10 01	H. Terminated	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	013
b. CONTRIBUTING				
c. XXXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)

(U) Models of Heat Disabilities: Predisposing Factors (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS

016200 Stress Physiology; 013400 Psychology; 003500 Clinical Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER: NOT APPLICABLE

c. TYPE d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	4.5	125
	CURRENT		

19. RESPONSIBLE DOD ORGANIZATION

NAME: USA RSCH INST OF ENV MED

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RESPONSIBLE INDIVIDUAL

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20. PERFORMING ORGANIZATION

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

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SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: HUBBARD, Roger, Ph.D.

NAME: FRANCESCONI, Ralph P., Ph.D. DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Heat Stress; (U)Heat Disabilities; (U)Body Temperature; (U)Military Disabilities

23. TECHNICAL OBJECTIVE. 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The use of model systems to study the effects of predisposing factors on the incidence and severity of disabilities, injuries and performance decrements associated with military operations in the heat.

24. (U) Models will be used to document and elucidate the role of obesity, dehydration, alcohol, drugs etc, in predisposing animals to heat illness.

25. (U) 78 10 - 79 09 In an experiment designed to quantitate the deleterious effects of consuming alcohol prior to working in the heat, we demonstrated that ingestion of increasing concentrations (4-16% of alcohol significantly reduces the endurance capacity of animals exercising at 35°C. The consumption of the higher concentrations of ethanol seems to be associated with hemoconcentration and lactacidemia which were both exacerbated after exercise in the heat. However, no effects of alcohol consumption were noted on circulating levels of glucose, potassium, or, surprisingly, total protein. Prior to using a heatstroke model developed in our laboratory to quantitate the effectiveness of either heat acclimatization, prehydration or drugs in reducing heatstroke mortality, it is necessary to further test the reliability of heatstroke mortality predictions. The reliability of 3 predictors were evaluated using the Mahalanobis D^2 statistic. The reliabilities of the maximum temperature of the body core, total hyperthermic area in degree.minutes, and the combined index (average predictive morality of both area and temperature) as predictors of mortality were found to be 0.75, 0.75 and 0.80, respectively. Thus, based on the Mahalanobis D^2 statistic, the use of the combined index enhanced the probability of a correct prediction of mortality. This work is terminated and research will be transferred to another work unit.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 013 Models of Heat Disability: Predisposing Factors

Study Title: Assessing the Reliability of Rat Heatstroke Mortality Predictions Using the Mahalanobis D^2 Statistic

Investigators: William T. Matthew and Roger W. Hubbard, Ph.D.

Background:

We previously reported that the incidence of rat heatstroke mortality can be predicted from dose-response curves of the severity of body heating. Hyperthermia was assessed by either the t core maximum or the calculated hyperthermic exposure measured as an area in degree-minutes above a baseline core temperature of 40.4C (1,2). Prior to using this model to quantitate the effectiveness of acclimatization (see companion report) or treatment, it is necessary to further test the reliability of these predictions.

Progress:

During the course of these investigations using either t core or thermal area to predict heatstroke mortality, it became apparent that in many individual rats mortality predicted by one of these variables differed greatly from mortality predicted by the other. Although a matter of concern, this observation on the variable response of individual rats was not of paramount importance since the experimental designs employed measured the collective responses of large populations to extremely different situations such as the response to heat plus exhaustive exercise versus heat alone. Current protocols, however, designed to test both individual and group responses to more subtle forms of manipulation require a high degree of predictive reliability. The following analysis represents an effort to accommodate both measures through a combined prediction variable that would be more reliable than either of the others alone. For this test, we used data from a prior report. A trial group of 82 fasted rats of approximately 500 g was selected. This group was heated to maximum core temperatures which ranged from 41.0 to 43.3C. Total thermal area above baseline ranged from

7.5^{o} min to 97.4^{o} min. Sixty (60) animals survived and 22 animals died within 24 h. Dose-response curves of percent mortality versus either t core-max or total hyperthermic area were constructed using the method of Reed and Muench (1). The Reed-Muench method for estimating lethal dose (LD) was used to determine the shape of the original curves for heatstroke mortality with 24 h (Figures 1A and 1B). It was also used to evaluate the effectiveness of the linearization process in the observed vs. predicted mortality curves, (Figures 2A and 2B) and the combined curve, Figure 4. Following is an example of the Reed-Muench procedure using maximum core temperature as dose.

Reed-Muench Procedure

INTERVAL	MEAN CORE TEMP. (DOSE)	N	ALIVE	DEAD	ACCUMULATED ALIVE	ACCUMULATED DEAD	ACCUMULATED TOTAL	%
41.3 - 41.5	41.30	1	1	0	58	0	58	0
41.5 - 41.7	41.57	6	5	1	57	1	58	1.7
41.7 - 41.9	41.78	16	16	0	52	1	53	1.9
41.9 - 42.1	41.96	10	10	0	36	1	37	2.7
42.1 - 42.3	42.14	9	6	3	26	4	30	13.3
42.3 - 42.5	42.34	16	12	4	20	8	28	28.6
42.5 - 42.7	42.55	10	6	4	8	12	30	60.0
42.7 - 42.9	42.76	9	2	7	2	19	21	90.5
42.9 - 43.1	42.91	2	0	2	0	21	21	100.0

It should be noted, however, that the Reed-Muench process artifically increases the number of animals exposed to a given "dose" of hyperthermia. The basic assumption is that an animal succumbing to a given heat dose would have succumbed to all higher doses and, conversely, an animal surviving a given heat dose would have survived all lower doses. The actual results are shown below (Figures 1A and 1B).

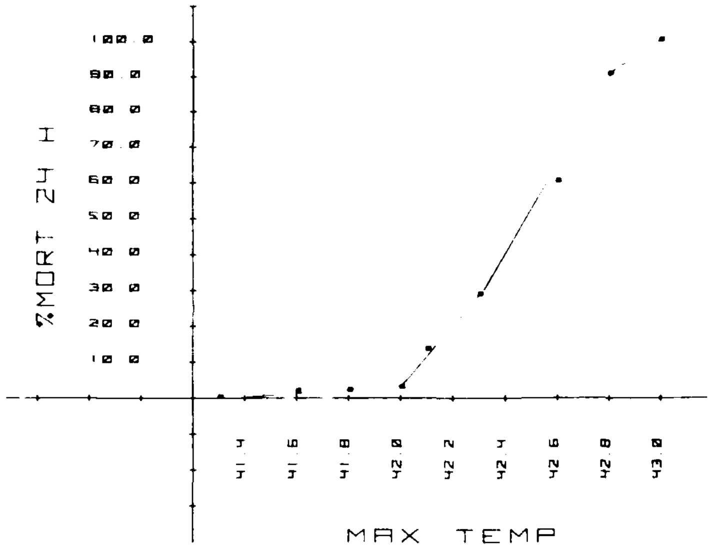

Figure 1A. Dose-response curve of percent mortality within 24 h vs maximum core temperature n = 82. Mean $\pm$ S.D. = 42.2 $\pm$ 0.4C. Survivors only: n = 60, Mean $\pm$ S.D. = 42.0 $\pm$ 0.4C. Fatalities only: n = 22, Mean $\pm$ S.D. = 42.5 $\pm$ 0.4C. LD 50 $\pm$ S.E. = 42.4 $\pm$ 0.1C.

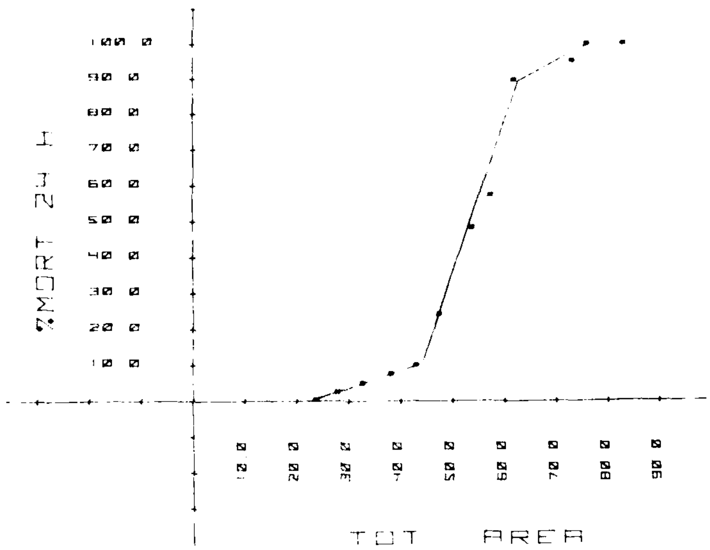

Figure 1B. Dose-response curve of percent mortality within 24 h versus thermal area above 40.4C measured in degree-minutes. Thermal area (deg.min) = time interval (2 to 6 min) x 1/2 (^{O}C at start of interval + ^{O}C at end of interval) -40.4 . n = 82. Mean $\pm$ S.D. = 43.7 $\pm$ 16.7. Survivors only: n = 60, Mean $\pm$ S.D. = 38.5 $\pm$ 13.6. Fatalities only: n = 22, Mean $\pm$ S.D. = 57.9 $\pm$ 16.4. LD 50 $\pm$ S.E. = 51.7 $\pm$ 3.4 degree minutes.

The sigmoid dose-response curves based on maximum core temperature (Figure 1A) and thermal area (Figure 1B) were divided into segments that were approximately linear. Slope and y-intercept constants were derived for each segment of both curves. The appropriate constants were then applied to the maximum core temperature and thermal area data for each rat. This provided an estimate of the level of heat stress sustained by each animal in terms of: 1) a predicted mortality based on maximum core temperature, LD:T and, 2) a predicted mortality based on thermal area, LD:A. To verify the effectivenss of the linearization procedure, LD:T and LD:A data were processed using the Reed-Muench method and the results are shown in Figure 2A and 2B.

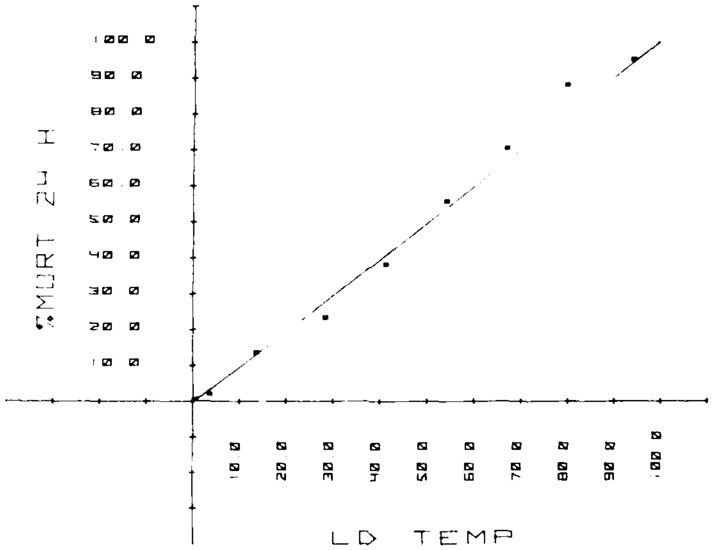

Figure 2A. The relationship between the observed mortality (% mort. 24 h) and the predicted LD: Temp. Linear regression of the observed mortality against the mortality (interval mean) predicted by LD:T yielded: slope = 1.08; y intercept = 5.1; std error of estimate = 3.4%; R = 0.992.

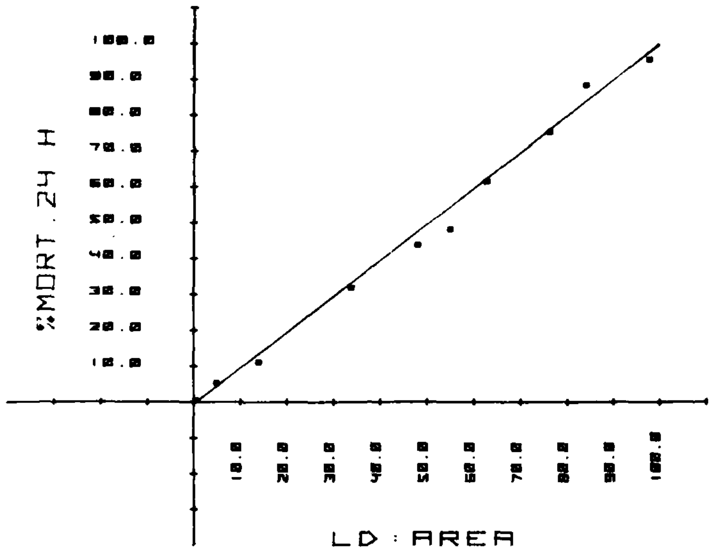

Figure 2B. The relationship between the observed mortality (% mort. 24 h) and the predicted LD: Area. Linear regression of the observed mortality against the mortality (interval mean) predicted by LD:A yielded slope = 1.01; y intercept = 2.7; std error of estimate = 3.2%; R^2 = 0.991.

These figures demonstrate that the linearization constants applied to max core temperature and thermal area do indeed result in a predictive scale of 0 to 100% mortality that is essentially linear and identical to observed mortality.

Figure 3 serves to illustrate the frequently contradictory nature of temperature and area mortality predictions for individuals and, further, suggests the need for some rational combination of these predictors to provide a more comprehensive index for individual mortality prediction.

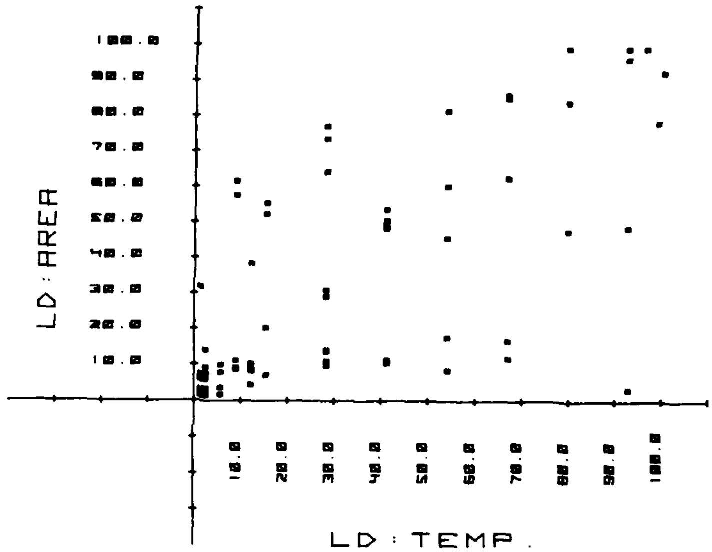

Figure 3. The relationship between LD:A and LD:T is shown above. This data was not processed through the Reed-Muench Method and serves to illustrate the frequently contradictory nature of the assessment of heat dose in individuals by maximum core temperature and thermal area. Linear regression of LD:A against LD:T yielded: slope = 0.768; y - intercept = 7.06; std. error of estimate = 22%; R^2 = 0.555.

The initial approach to this problem has been to calculate a simple average of the two LD's, (LD:A + LD:T)/2 for each individual. These data, were then processed using the Reed-Muench method. When the observed mortality was plotted against the mortality predicted by this combined index a distinctly sigmoid curve results (Figure 4).

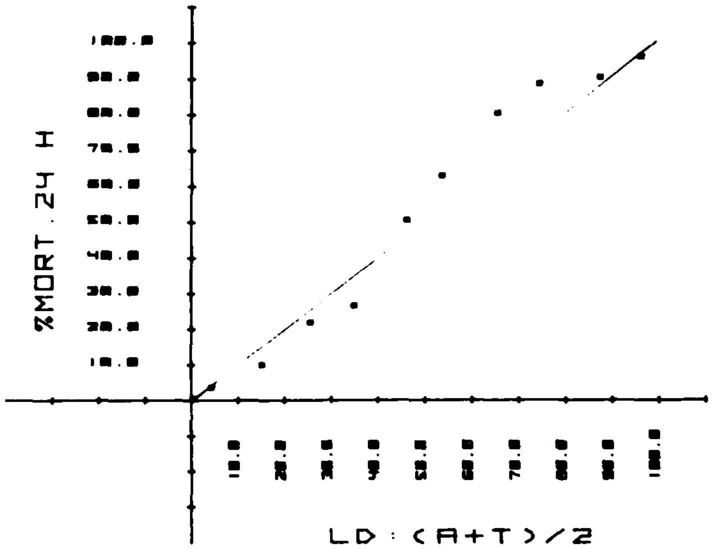

Figure 4. As a first step in dealing with the conflict between LD:A and LD:T predicted mortality, a combined index consisting of a simple average of the two LD's was calculated, (LD:A and LD:T)/2. These data, processed using Reed-Muench, were plotted and the results are shown above. Regression of the observed mortality against the mortality (interval mean) predicted by LD:(A and T)/2 yielded: slope = 1.129; y - intercept = -3.754; std. error of estimate = 7.3%; R^2 = .962.

The considerable deviation from linearity of this curve was surprising especially in view of the good linearity of the two individual curves, LD:A and LD:T from which it was derived. This result suggests that when these two indices are combined some scheme for differential weighting of the components is required. Work is in progress to determine the optimum weights for the LD:A and LD:T components of this index. At this point, however, it was decided to proceed with an evaluation of the reliability LD:A, LD:T and LD (A + T)/2

together with max core temperature and thermal area in terms of their ability to accurately discriminate between potential survivors and fatalities. To measure this reliability, the Mahalanobis D^2 statistic was employed. This statistic has been used in the evaluation of the reliability of a variety of medical diagnostic and predictive measures (2, 3, 4) as well as medical applications using computerized discriminant function analysis (5).

The reliabilities of the previously defined variables in predicting rat heatstroke mortality in the trial group of 82 rats are listed in Table 1. Although the reliability of LD:A was slightly better than raw thermal area and LD:T was considerably better than raw max core temperature, best reliability was achieved using the combined index LD:(A + T)/2. Thus, in spite of the somewhat compromised linearity of the combined index seen in Figure 4, LD:(A + T)/2 nevertheless provided the most reliable index for the prediction of mortality within this reference group.

TABLE 1 - Trial Group

VARIABLE	SURVIVORS (N=60)	FATALITIES (N=22)	MAHALANOBIS D^2	RELIABILITY*
Max. Core Temp.	42.0	42.5	1.870	75%
	$\pm$ 0.4	$\pm$ 0.4		
LD:T	18.7	60.0	2.486	79%
	$\pm$ 23.1	$\pm$ 33.3		
Thermal Area	38.5	57.9	1.814	75%
	$\pm$ 13.6	$\pm$ 16.4		
LD:A	19.3	59.1	2.056	76%
	$\pm$ 25.4	$\pm$ 33.6		
LD:(A + T)/2	19.0	59.5	2.771	80%
	$\pm$ 21.7	$\pm$ 30.5		

*Reliability estimated by the area under the normal probability curve to the left of D/2.
Mean $\pm$ STD. Deviation.

As a test of the applicability of these indices to other experimental designs, the linearization constants that were established using the trial group of 82 rats were applied to the max core temperature and thermal area data obtained in an acclimatization study (see companion report). The reliability of these computed variables in discriminating between potential survivors and fatalities were again evaluated using the Mahalanobis D^2 statistic. The results are shown in Table 2.

TABLE 2 - Acclimatization Study*

	MAX. CORE TEMP.	LD:T	THERMAL AREA	LD:A	LD:(A + T)/2
Experimental					
Mahalanobis D^2	1.382	2.369	1.356	0.976	2.604
Reliability	72%	72%	72%	69%	79%
Controls					
Mahalanobis D^2	0.977	0.822	0.615	0.435	1.128
Reliability	69%	67%	65%	63%	70%

*For details see companion report

The lowered reliability of the individual LD:A and LD:T indices in this experiment suggest a fundamental shift in the core temp/mortality and area/mortality relationship established in the reference (trial group of 82 rats. One possible explanation is that all the rats in the acclimatization study received repeated (5 days) familiarization sessions with the heat chamber restraining cage prior to final hyperthermic stress. Since even the control group in this study had lower heating rates than those in the reference group, there may have been some perturbation of the temperature and area mortality relationships established from the reference groups of 82 rats (which had no prior familiarization with the restraining cage). Nevertheless, the LD:(A + T)/2 again provided the most reliable index for the prediction of mortality in both control and experimental groups.

In summary, we have developed and statistically evaluated a more reliable predictor of heatstroke mortality thru the linearization and combination of two previously developed predictors, max core temperature and thermal area. Refinements in the weighting of the temperature and area components of this combined index, currently in progress, should result in further improvements in the overall reliability of rat heatstroke mortality predictions.

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2. Shubin, H., A. A. Afifi, W. M. Rand and M. H. Weil. Objective index of haemodynamic status for quantitation of severity and prognosis of shock complicating myocardial infarction. Cardiovasc. Res. 4:329-337, 1968.

3. Weil, M. H. and A. A. Afifi. Experimental and clinical studies on lactate and pyruvate as indicators of the severity of acute circulatory failure (shock). Circulation 41:980-1001, 1970.

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5. BMDP-77 Biomedical Computer Programs, P-Series. W. J. Dixon, Series Editor, M. B. Brown, Editor, 1977 Edition, University of California Press, Berkeley, CA, 1977.

Program Element: 6.11.02.A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness, and Medical Factors in Military Performance

Work Unit: 013 Models of Heat Disability: Predisposing Factors

Study Title: Effects of Alcohol Ingestion on Predisposition to Heat Injury

Investigators: Ralph P. Francesconi, Ph.D. and Milton Mager, Ph.D.

Introduction:

While it has been generally agreed that the chronic consumption of alcohol will have marked decremental effects on the ability to work in the heat, very little research has actually been designed and carried out to quantify the extent of the anticipated decrements. Since we have now collected a reasonably large data base on the physiological and thermoregulatory capacity of healthy normothermic animals, we believe that it is appropriate at this time to examine quantitatively the effects of conditions, such as chronic alcohol consumption, which may predispose to heat injury or compromise the ability to work in the heat.

In addition to its dehydration effects alcohol consumption has a myriad of adverse metabolic effects one of which is an inhibition of albumin synthesis (1). Recently, Senay (2) has hypothesized that the ability of heat-tolerant, but non-acclimatized individuals to undertake work in the heat is related to an influx of water and protein into the vascular volume. If this is true, then the combined dehydration and protein-synthesis inhibitory effects of alcohol consumption may have serious consequences on the ability to work in the heat. During this FY we have initiated a series of experiments to quantitate the extent of the disability incurred by alcohol consumption, and this is a preliminary report of these findings.

Progress:

To estimate the intensity of alcohol-induced decrements in the ability to work in the heat, alcohol/water mixtures (4, 8, 12, or 16% of 100% ethyl alcohol in water) was supplied to the rats as the sole source of drinking water for 13-14 days prior to experimentation. On the day before an exhaustive run (9.14 m/min) in a hot (35°C)

environment, these rats were fitted with indwelling jugular catheters for the removal of a small volume (1 ml) of blood immediately prior to and subsequent to the exercise to hyperthermic exhaustion (42.5^{o} - $43^{o}C$). These blood samples have been deep-frozen and will be analyzed quantitatively to assess the effects of hyperthermic exhaustion on some common clinical chemical indices of heat injury.

To date, our results have demonstrated that consumption of increasing concentrations of alcohol in the drinking water decreases the endurance capacity of rats exercising in the heat (Figure 1). For example, whereas rats which had consumed 4% alcohol for 13 days had an endurance capacity of 32 min (not significantly different from controls), rats which had consumed 16% ethanol for the same length of time had an endurance capacity of 22.7 min (4% vs 16%, $p < .001$). The arrows noted on the figures denote the average time to hyperthermic exhaustion among the four groups of rats. No marked differences occurred in these animals with respect to rate of Tre increase while exercising on the treadmill. Similarly, Figure 2 illustrates essentially no differences among these groups of animals in increments of T_{sk} during exercise in the heat; this can be interpreted that heat dissipation mechanisms are not severely affected by consumption of up to 16% alcohol for two weeks. These results are summarized in the data presented in Table 1. Surprisingly, consumption of increasing concentrations of alcohol had no effects on hematocrit levels or survivability of the animals following incursions of the heat injury. Effects of alcohol consumption on the clinical chemical correlates of heat injury are currently being determined.

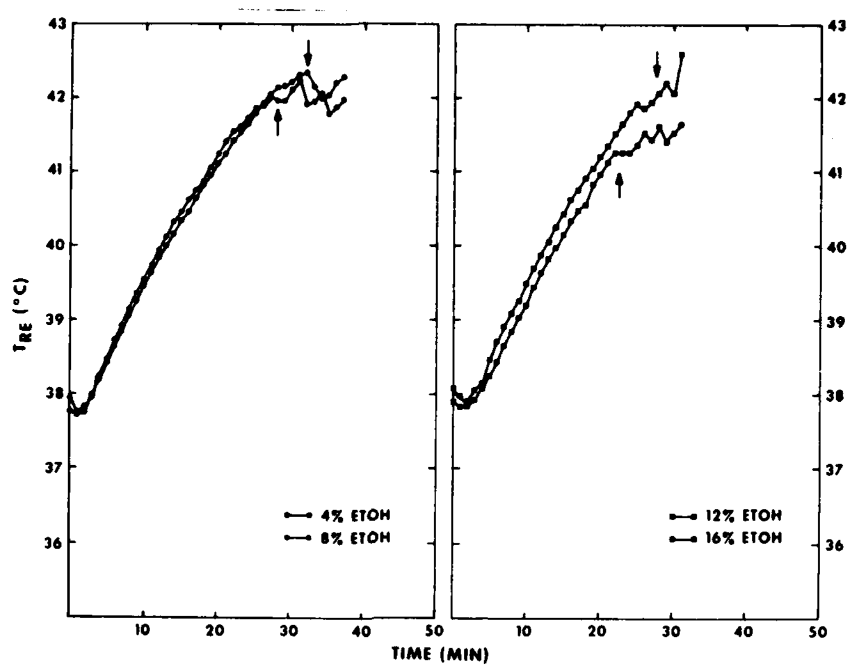

Figure 1. Responses of rectal temperature to exercise in a hot environment after the rats had drunk various concentrations of ethyl alcohol in the drinking water for two weeks prior to experimentation.

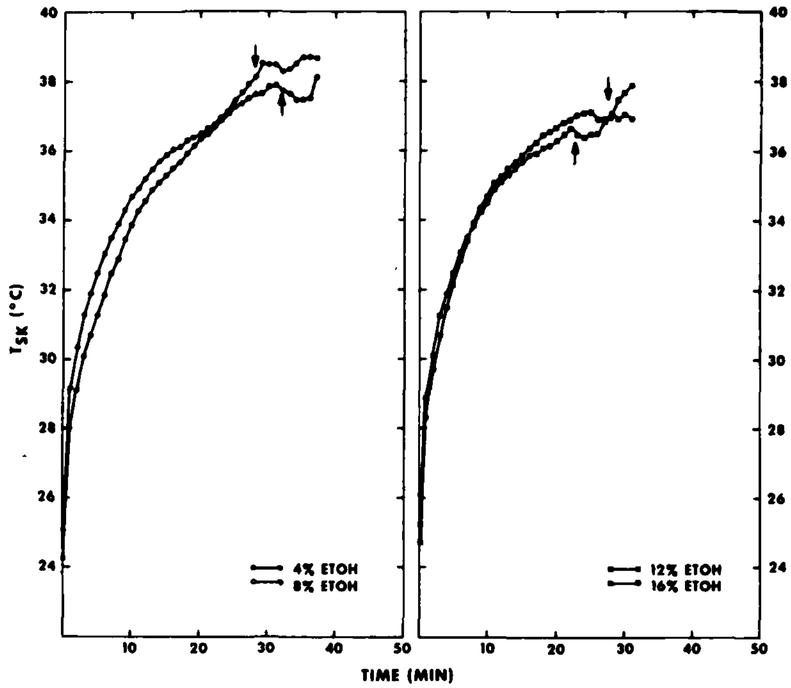

Figure 2. Skin temperature response to exercise in a hot environment after the rats had drunk various concentrations of ethanol in the drinking water for two weeks prior to experimentation.

TABLE 1

Summary of the data presented in Figures 1 and 2

		TIME ON TREADMILL (MINUTES)	RECTAL TEMPERATURE MAXIMUM (°C)	ΔT_{RE}/MIN ON TREADMILL (°C)	SKIN TEMPERATURE MAXIMUM (°C)	ΔT_{SK}/MIN ON TREADMILL (°C)	VOLUME CONSUMED
4% ETOH	$\bar{X}$	32.0	42.63	.153	37.81	.423	351.3
	$SE_{\bar{X}}$	1.0	.09	.009	.24	.018	17.9
8% ETOH	$\bar{X}$	28.09	42.37	.160	37.26	.438	259.1
	$SE_{\bar{X}}$	1.40	.13	.009	.34	.016	18.6
12% ETOH	$\bar{X}$	27.62	42.30	.153	37.25	.454	323.6
	$SE_{\bar{X}}$	.80	.13	.004	.34	.02	27.3
16% ETOH	$\bar{X}$	22.72	41.22	.145	36.22	.511	252.3
	$SE_{\bar{X}}$	1.94	.36	.010	.43	.039	19.1

A number of factors have been identified (alcohol, phenothiazine drugs, low-grade fever) which are both of interest to military planners and of consequence to the ability to work in the heat, i.e. they can be expected to limit physical performance in the heat. Therefore, it is anticipated that continued research will be directed at elucidating and quantitating the effects of these factors on work in the heat. Current protocols call for an investigation of both phenothiazine drugs (e.g. chlorpromazine) and low-grade fever (e.g. Pseudomonas polysaccharide) on the ability to work in the heat.

Presentations:

Mager, M. and R. P. Francesconi. Effect of hypothermia induced by chlorpromazine or L-tryptophan on treadmill performance in the heat. Fed. Proc. 38:1052, 1979.

LITERATURE CITED

1. Rothschild, M. A., M. Oratz, J. Mongelli and S. S. Schreiber. Alcohol-induced depression of albumin synthesis: reversal by tryptophan. J. Clin. Invest. 50:1812-1818, 1971.

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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION	2. DATE OF SUMMARY	REPORT CONTROL SYMBOL
				DA OC 6124	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	D. Change	U	U	NA	NL	☐ YES ☐ NO	A. WORK UNIT

10. NO./CODES:	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	014
b. CONTRIBUTING				
c. ~~CONTRIBUTING~~	CARDS 114f			

11. TITLE (Precede with Security Classification Code) (U) Cell Culture Modeling of Cellular Disabilities Associated with Environmental Extremes (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS
005900 Environmental Biology; 010100 Microbiology; 002300 Biochemistry

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
77 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER: NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	3.5	151
	CURRENT 80	1	31

19. RESPONSIBLE DOD ORGANIZATION

NAME: USA RSCH INST OF ENV MED
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TELEPHONE: 955-2861
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: HAMLET, Murray P., D.V.M.
NAME: 955-2865 DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Tissue Culture; (U)Endothelial Cells; (U)Frostbite; (U)Ultrastructure

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) *In vivo* studies have concluded that an intact vascular system is necessary to prevent necrosis of frozen tissue. More specifically, the fate of endothelial cells lining the vascular system appears to be important to the eventual prognosis. This study proposes to develop an *in vitro* tissue culture model suitable for studying cold induced endothelial cell damage. This will hopefully result in an *in vitro* human endothelial cell model with direct application to human frostbite *in vivo*.

24. (U) Calf aorta endothelial cells will be grown *in vitro*. Some cells will be grown at 37°C as controls while others will be exposed to various above- and below-freezing temperatures for various time periods. Ultrastructure damage will be monitored via two types of electron microscopy, light microscopy and release of cellular enzymes.

25. (U) 78 10 - 79 09 The *in vitro* endothelial cell model is being used to study the interaction of bovine platelets with endothelial cells subjected to freeze-thaw conditions. Preliminary results indicate that platelets rarely adhere to either control (37°C) or freeze-thaw damaged endothelial cells. Platelets do adhere to the extracellular matrix underlying the cells which is exposed following freeze-thaw. In addition, platelets adhering to the extracellular fibers are for the most part individual platelets and no extensive aggregation results. Studies are ongoing to determine if platelets will adhere to the network of intracellular filaments and microtubules exposed following treatment with Triton-X-detergent.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

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Program Element: 6.11.02 A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 014 Cell Culture Modeling of Cellular Disabilities Associated with Environmental Extremes

Study Title: Development of an In Vitro Endothelial Cell Model As It Applies to Cold Induced Ultrastructural Changes

Investigators: Lynn R. Trusal, CPT, MSC, Ph.D. and Murray P. Hamlet, D.V.M.

Background:

The importance of an intact vascular system to tissue survival following frostbite injury has been demonstrated (5). It is also known that endothelial cells lining the vascular system are non-thrombogenic unless the cells are removed, exposing the subendothelium. Freeze-thaw damage to blood vessels is known to initiate clotting mechanisms leading to hemostasis and possible loss of limbs by tissue necrosis. Thus, ultrastructural damage to endothelial cells lining the blood vessels appears to be the initial event leading to hemostasis following an in vivo freeze-thaw injury. Because platelet aggregates are the blood stream's first line of defense against hemmorrhaging; their role in post-frostbite hemostasis warrants study. This should help to elucidate the role of the platelets in the particular clotting mechanisms activated by freeze-thaw damage.

Progress:

The ultrastructural appearance of cells exposed to varioms above and below freezing temperatures at physiological osmolarity (310 mOsm) may be summarized as follows.

Control cultures of bovine endothelial cells maintained at 37°C exhibited morphology of typical healthy cells. Membranes were intact and euchromatin and heterochromatin were characteristically distributed throughout the nucleus. The cytoplasm contained numerous mitochondria, thin filaments, microtubules and pinocytotic vessicles (Fig. 1). Figure 2 is a scanning electron micrograph showing control (37°C) cells in monolayer culture in close apposition to each other.

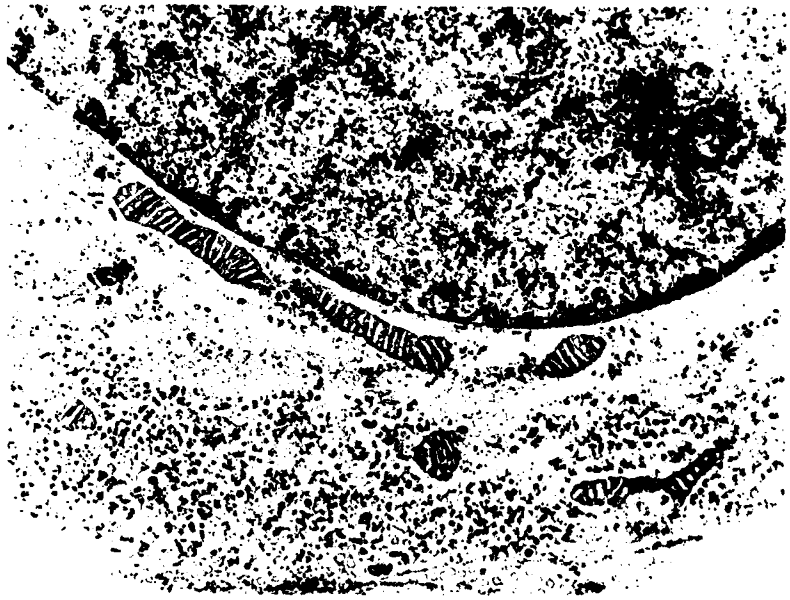

Figure 1. Transmission electron micrograph of control ($37^{o}C$) bovine endothelial cell.

Figure 2. Scanning electron micrograph of control ($37^{o}C$) bovine endothelial cells.

Experimental cultures exhibited a wide range of ultrastructural damage as result of the freeze-thaw insult. Alterations could generally be characterized as either membrane changes or changes in distribution of cellular constituents. The organelles which appeared most sensitive to freezing were mitochondria. Even in cells exposed to -10°C and not frozen some mitochondria exhibited cristae swelling and increases in the intramembranous compartment. The outer membranes remained intact and were only disrupted in the most severely damaged cells. In cultures frozen at -15°C or -20°C, almost all mitochondria contained swollen inner membranes which may also exist in a twisted configuration (Fig. 3). These mitochondria bear a strong resemblance to isolated mitochondria having undergone electron transport and referred to as existing in an "energized" or "energized-twisted" state (1).

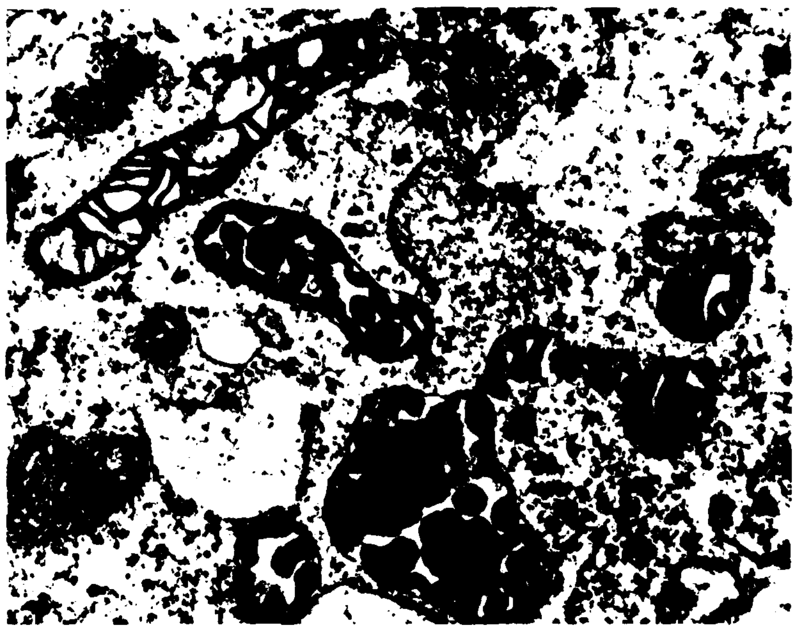

Figure 3. Transmission electron micrograph of freeze-thawed (-15°C) mitochondria exhibiting swollen and distorted inner mitochondrial membranes.

Another cellular structure sensitive to freezing was the nuclear membrane. In some frozen cells, the chromatin remained distributed in regions of heterochromatin and euchromatin similar to controls, but separation and distortion of the nuclear envelope were seen to occur. The membrane bilayers became separated and the entire envelope bulged away from the peripheral adjacent heterochromatin (Fig. 4). Thus, the membranes often have a wavy appearance. Although the plasma membrane of the cell itself was also severely disrupted in frozen cells, many adjacent cells had contiguous membranes.

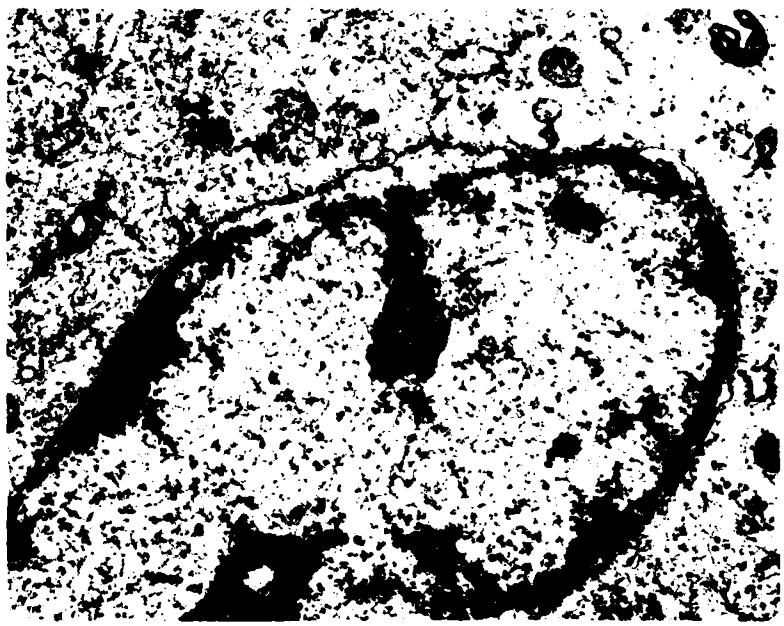

Figure 4. Transmission electron micrograph of distorted nuclear membrane and clumped chromatin in a freeze-thawed (-15°C) endothelial cell.

Other organelles in the cytoplasma also become swollen or disappeared including the microtubules and endoplasmic reticulum. Ribosomes and thin filaments were seen scattered throughout the remaining cellular debrie.

Figure 5 illustrates the use of measuring cellular enzyme release as a secondary means of assessing ultrastructural damage. Endothelial cells released large quantities of the cytoplasmic enzyme lactic dehydrogenase when freeze-thawed.

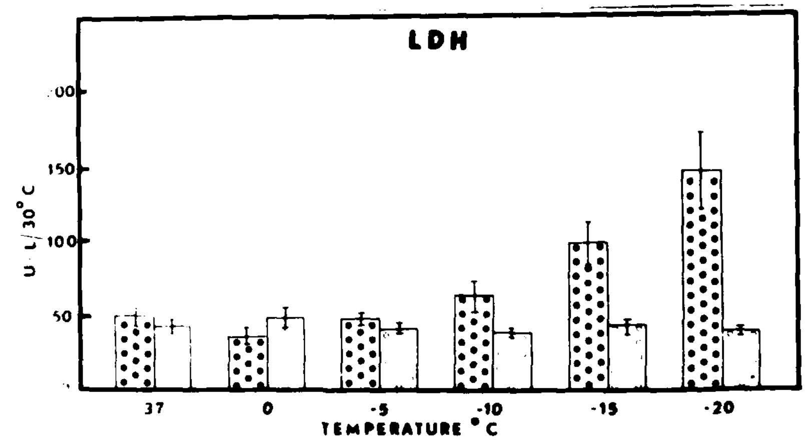

Figure 5. Bar graph of lactic dehydrogenase release from bovine endothelial cells following exposure to various temperatures (°C).

Since frostbite is usually considered to occur in vivo at a tissue freezing rate of approximately 1.0°C/min, we have utilized freezing rates in vitro of between 0.5 and 1.0°/minute to assay the response of endothelial cells to a freeze-thaw insult. At such a freezing rate, actual intracellular ice crystal formation is rare and cellular changes are believed to be largely the result of osmotic damage from concentration of electrolytes.

In order to test this hypothesis, we are currently exposing cultures to increasing osmotic concentrations in the standard tissue culture media and examining them by light and electron microscopy.

We have extended the usefullness of the in vitro model and have begun examining the interaction of bovine platelets with both control and experimental cultures of endothelial cells. Cells were grown to confluence on plastic coverslip substrates and either maintained at 37°C (control) or exposed to various temperatures (0°, -10°, -15°, -20°C) above and below freezing. All coverslips were then returned to 37° with the frozen ones thawed at a rate of approximately 20°C/minute. These coverslips were then placed in a specially designed flow chamber to simulate a blood vessel wall.

Bovine platelets were obtained from calf citrated blood at a local slaughterhouse. A platelet rich plasma (PRP) sample was prepared by differential centrifugation and the PRP was then gel filtered using a Sephrase 2B column with a Tyrodes elution buffer. These gel filtered platelets (GEP) were separated from plasma proteins in a gentle manner and were recovered as a fairly homogenous population. GFP have been shown to be morphologically intact and capable of responding to various aggregating agents such as ADP (2). The GFP were then perfused thru the chamber containing the coverslips for 30 min at 37°C. This was followed by washing to remove non-adhering platelets and fixation for both light and electron microscopy (TEM and SEM).

Preliminary examination by both light and SEM revealed some platelets attached to cellular processes at the edge of some cells or to the extracellular matrix produced by the cells and located beneath them. Platelets did not appear to attach directly to the plasma membrane of the control (37°C) cultures. Both observations are consistent with published reports of platelet endothelial interaction for non-damaged and non-activated control cultures (6).

In experimental cultures, freeze-thawing resulted in removal of some cells thereby exposing the extracellular fiberous matrix. This matrix has been shown to contain the glycoprotein fibronectin which is also known as cold-insoluble globulin. Fibronectin is also found in vivo in plasma and basement membrane (3). It is important to note that the basement membrane of capillaries is a reactive surface for platelet adherence which may be related to the presence of fibronectin in the membrane (4). Therefore, the presence of fibronectin in vitro underlying cultured endothelial cells may have a correlation to basement membrane underlying endothelial cells in some blood vessels in vivo.

Both light microscopy and SEM examination demonstrated attachment of platelets to this extracellular matrix, in both experimental and control cultures.

Platelets were also seen adhering to the plasma membrane of some cells (-15°C) following perfusion, washing and fixation. There was no evidence of platelet aggregation or the release reaction having occurred in these attached platelets. They appeared to be devoid of extensive shape changes or pseudopodia formation. Attachment therefore appeared to be a singular event. The lack of a platelet aggregometer prevented testing to determine if frozen-thawed cells release substances capable of initiating aggregation. This will be tested in the coming year. Although endothelial cells predominate in culture, there are also smooth muscle cells which have been shown to allow platelet attachment. Preliminary results were not sufficiently conclusive to establish whether or not platelets adhered to freeze-thaw damaged endothelial cells themselves or the the small number of smooth muscle cells present.

In addition to extracellular microfibrils, collagen and basement membrane which exist in the subendothelium and are known to initiate platelet adherence and aggregation, the cell also contains a network of intracellular fibers. These consist of microfilaments, intermediate filaments and microtubules which make up the cytoskeleton of the cells. Cytoplasmic membrane disruption which can occur from freezing and thawing may result in exposure of this filament network to circulating platelets. It is unknown if intracellular fibers can initiate platelet adherence and aggregation. This will be tested by the exposure to the cytoskeleton with a non-ionic detergent, Triton-X-100, which digests the cytoplasma leaving behind the cytoskeleton. Circulating platelets in Tyrodes buffer will be interacted with the intracellular fiber network to ascertain their ability to cause platelet adherence and aggregation.

Another planned experiment deals with utilizing the whole aorta in vitro. In this manner, the response of freeze-thaw damaged endothelium to circulating platelets or to citrated whole blood may be tested in a more in vivo like environment but one in which variables may be more closely controlled. An aorta segment will be perfused with buffer at either 37°C or at various temperatures above and below freezing. Following return to 37°C, tyrodes buffer containing platelets will then be perfused for up to 30 min. Following washing and fixation, the various aorta segments will be prepared for

examination by light, scanning and transmission electron microscopy. The in situ interaction of platelets with the intimal blood vessel surface will then be examined.

Publications:

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RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION	DA OC 6132
2. DATE OF SUMMARY	79 10 01
REPORT CONTROL SYMBOL	DD-DR&E(AR)636
3. DATE PREV SUM'RY	79 04 30
4. KIND OF SUMMARY	D. Change
5. SUMMARY SCTY	U
6. WORK SECURITY	U
7. REGRADING	NA
8a. DISB'N INSTR'N	NL
8b. SPECIFIC DATA-CONTRACTOR ACCESS	☒ YES ☐ NO
9. LEVEL OF SUM	A. WORK UNIT

10. NO./CODES:	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.11.02.A	3E161102BS08	00	015
b. CONTRIBUTING				
c. XXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code) (U) Survey Analysis of Environmental Medical Symptoms and Risk in Army Personnel (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS 007900 Occupational Medicine; 012500 Personnel Selection, Training; 005900 Environmental Biology; 013400 Psychological; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
79 05	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:
b. NUMBER: NOT APPLICABLE
c. TYPE: d. AMOUNT:
e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	.7	10
	CURRENT 80	4	157

19. RESPONSIBLE DOD ORGANIZATION

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ASSOCIATE INVESTIGATORS
NAME: STOKES, James W., LTC, MC
NAME: 955-2822 DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Survey Analysis; (U)Symptoms Self-Reports; (U)Questionnaires/Interviews; (U)Climatic Exposure; (U)Health Risk Factors; (U)Rating Scales

23. TECHNICAL OBJECTIVE. 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Data is needed on the number and type of Army personnel who suffer environmentally-induced illness and injury, on therapies used and their effectiveness, on troops exposed but never requiring treatment, on partially disabling symptoms which may go unreported, on the nature of exposure (especially as related to MOS duties) and on medical risk factors due to individual background, physical condition and health-related behaviors. Such data, obtained from and published in terms of actual Army populations, will give focus to research, prophylaxis and training, and be of direct use to operational planners, commanders, and at-risk individuals.

24. (U) Develop and field test specific methodologies for data collection and analysis from Army personnel who are exposed to climatic extremes and/or sustained operations during field maneuvers, special training, or transmeridian deployments and to rigorous physical fitness programs. Methodology includes questionnaires, interviews record surveys and behavioral observations designed to obtain subjective and objective data on illness and injury as well as relevent background information. The methodology will also be used in controlled laboratory experiments where climatic conditions are manipulated. Development involves coordination with other agencies, training of personnel and the pretest, sample test, revision and validation of survey instruments. Survey sampling statistics will be applied to determine confidence level and to describe subjects in terms of percentiles in select Army subpopulations. It is expected that the perfected procedures will be used in applied work units.

25. (U) 79 05 - 79 09 This work unit was created to conduct operational testing of questionnaires and procedures developed under ILIR, WU 020. The Environmental Symptom Questionnaire was administered in a USARIEM laboratory study. Consultations with MILPERCEN, OTEA, WRAIR, West Point MEDDAC, and 9th Inf Div Surgeon explored future applications.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.11.02. A DEFENSE RESEARCH SCIENCES, ARMY

Project: 3E161102BS08 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 015 Survey Analysis of Environmental Medical Symptoms and Risk in Army Personnel

Study Title: Factor Analysis of Symptom Structure of the Revised Environmental Symptom Questionnaire (ESQ)

Investigators: James B. Sampson, Ph.D. and James W. Stokes, M.D., LTC, MC

Background:

The Environmental Symptoms Questionnaire (ESQ) was developed at USARIEM in order to provide an easily administered but reliable subjective symptom inventory (1). Although the original ESQ was based largely on symptoms of acute mountain sickness (AMS) it was intended to be a general all-purpose survey instrument. Expanding an AMS symptom questionnaire into a more general questionnaire was relatively easy since most of the AMS symptoms were common to many other medical conditions.

The first version of ESQ was tested during a 1977 study at Pikes Peak where it was compared to the General High Altitude Questionnaire (GHAQ). The inventory was judged to be an improvement over the GHAQ in item structure, ease of administration and scale structure (1). However, even with these general improvements there appeared to be a problem with the scale. Certain commonly reported symptoms were not observed during sea level pre-exposure trials and by the fourth day at altitude. For symptoms such as headache, this was considered unusual. Therefore, the ESQ scale was revised. Rather than have a two stage response (yes - no, then a scale response of severity) a single response scale was adopted. The new scale ranges from 0 to 5 and has a verbal label for each value. This type of scale is in common use in other inventories (2). In addition, the revised ESQ, also included symptoms of depressed mood, fatigue, physical exertion, muscular complaints, thermal stress, blast over-pressure stress and sinus or upper respiratory irritation.

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Progress:

This second version of the ESQ was administered during a study on the effects of transatlantic flight on the physical work capacity performance of Army enlisted men being transferred from Texas to Germany (3) which is further described in this Annual Report under WU 009. In brief, ninety-four soldiers from two rifle companies at Fort Hood, Texas volunteered with the understanding that they could freely leave the study at any time without prejudice or penalty. Following the physical examinations, thirteen men were excluded for medical reasons. Eighty-one men were then randomly assigned to three groups. Each group was tested separately on three tasks, one task per day, in a counterbalanced sequence. The task sets were 1) field performance tests involving a 6-meter rope climb, a 125-yard man lift and carry, a 300-yard sprint and a 1.5 mile run; 2) isometric and dynamic tests of muscle group strength and endurance; 3) the Taylor interrupted uphill treadmill test of aerobic power.

The study employed a pre-post deployment test design. Subjects were tested on five consecutive days prior to, and five consecutive days immediately following deployment by commercial airliner to Germany. The symptom questionnaires were administered immediately before and immediately after each exercise session. In addition, all subjects were given the questionnaire twice during the flight to Germany. Thus each subject was surveyed twenty-two times throughout the study.

Data from the 45 subjects who completed questionnaires on all study days were submitted to a Principle Factor Analysis with iterations for improving estimates of commonality. Based on sample size, the decision was made to restrict the number of factors to five. The initial factoring was followed by a Varimax Orthoganal Rotation for simplifying the factor structure (4). It should be pointed out that one main assumption was violated in the present analysis, namely, that each case is an independent observation. Since data represents only 45 subjects repeatedly tested over 22 trials (45 x 22 = 990 cases) the resulting structure is biased toward the response tendencies of the 45 subjects tested. The probable effect of this is an overestimation of the amount of variance accounted for in the resulting factors. Only future studies will determine the acceptability of the present factor structure. However, because the resulting factors have high face validity it was decided to accept them as useful but tentative.

The five factors which emerged are summarized in Table 1. The table gives the factor label, the amount of variance accounted for and the weights given to each significant factor (cut off was .300). The first factor was a Physical Exertion Factor, and accounted for 49.7% of the variance. The leading items, in order of importance, were breathing fast, heart fast, breathing irregular, heart pounding, hard to breathe, muscles tense, sweating and mouth dry. The remaining items also fell within the concept of exertion, thus making this factor fairly clear cut. The second factor was a fatigue factor accounting for 17.5 percent of the variance. The leading items included: tired, sleepy, irritable, feel weak, trouble sleeping, poor concentration, clumsy, muscles ache and eyes irritated. This factor contained some mood and psychomotor items suggesting some behavioral component to the sensation of fatigue. The third factor was labeled EENT for eyes, ears, nose and throat irritation, and accounted for 13.3% of the variance. The leading items included: eyes watery, eyes irritated, nose bleeding, ears ache, ringing ears, ears blocked, vision blurry and nose blocked. The fourth factor involved head throbbing, headache, lightheaded, faint, feel warm, nausea, stomach upset and balance off. This was simply labeled "Headache-Nausea" and accounted for 10.3 percent of the variance. The last factor was a "Wellness" factor with the items: feel well, feel happy, clear thinking, negatively weighted stomach pressure and stomach upset.

Questionnaires of the 45 men who completed all trials in the Jet Lag study were next rescored to determine weighted scores for the five factors. All post exercise scores were compared to the inflight scores for statistical analysis. (As will be evident below, the inflight data proved more interesting for comparison than the pretest score of the 1st day, although differences were lower in magnitude).

Results are shown in Figure 1a and b. Except for Wellness, all five factors showed significant changes across trails based on a 1-way analysis of variance ($p < .01$). A critical difference test was used to compare individual trial means to the control trial.

TABLE 1. (Part I) Item Weights for the Five Factors of the ESQ

	SYMPTOM	I EXERTION (49.7%)	II FATIGUE (17.6%)	III EENT (13.3%)	IV HEADACHE NAUSEA (10.3%)	V WELLNESS (9.1%)
1.	HEADACHE	-	-	-	.620	-
2.	HEAD THROBBING	-	-	-	.632	-
3.	LIGHT HEADED	-	-	-	.542	-
4.	FAINT	-	-	-	.496	-
5.	RINGING EARS	-	-	.447	-	-
6.	HARD TO BREATHE	.597	-	.351	-	-
7.	BREATHE FAST	.792	-	-	-	-
8.	BREATHE IRREG.	.662	-	-	-	-
9.	NAUSEA	-	-	-	.437	-
10.	STOM. PRESSURE	.345	-	.309	-	-.337
11.	STOM. PAINS	.344	-	-	-	-
12.	STOM. UPSET	-	-	-	.398	-.328
13.	DIARRHEA	-	-	-	-	-
14.	CONSTIPATION	-	-	-	-	-
15.	URINATE FREQ.	-	-	-	-	-
16.	HEART FAST	.668	-	-	-	-
17.	HEART POUND	.655	-	-	-	-
18.	HEART IRREG.	.453	-	-	-	-
19.	MUSCLES TENSE	.509	.389	-	-	-
20.	MUSCLES ACHE	.442	.427	-	-	-
21.	BACK PAIN	-	.338	-	-	-
22.	CHEST PAIN	.460	-	-	-	-
23.	FEEL WEAK	.323	.577	-	-	-
24.	FEEL COLD	-	-	-	-	-
25.	FEEL CHILLY	-	-	-	-	-
26.	SHIVERING	-	-	-	-	-
27.	FEEL WARM	.419	-	-	.473	-
28.	FEVERISH	-	-	.312	-	-
29.	HANDS SWEATY	.334	-	-	-	-

TABLE 1. (Part II) Item Weights for the Five Factors of the ESQ

SYMPTOM	FACTORS I EXERTION (49.7%)	II FATIGUE (17.6%)	III EENT (13.3%)	IV HEADACHE NAUSEA (10.3%)	V WELLNESS (9.1%)
30. SWEATING	.498	-	-	-	-
31. SKIN SENSITIVE	-	-	.353	-	-
32. EYES IRRITATED	-	.425	.527	-	-
33. EYES WATERY	-	.354	.553	-	-
34. VISION BLURRY	-	-	.402	-	-
35. NOSE BLOCKED	-	-	.355	-	-
36. NOSE RUNNING	-	-	.329	-	-
37. NOSE BLEEDING	-	-	.508	-	-
38. EARS BLOCKED	-	-	.418	-	-
39. EARS ACHE	-	-	.455	-	-
40. CAN'T HEAR	-	-	-	-	-
41. MOUTH DRY	.469	-	-	-	-
42. SORE THROAT	-	-	.340	-	-
43. BALANCE OFF	-	.342	-	.373	-
44. CLUMSY	-	.435	-	-	-
45. TIRED	-	.709	-	-	-
46. SLEEPY	-	.706	-	-	-
47. CONCENTRATION	-	.470	-	-	-
48. MEMORY	-	-	-	-	-
49. WORRIED	-	.312	-	-	-
50. BORED	-	.340	-	-	-
51. IRRITABLE	-	.521	-	-	-
52. TROUBLE SLEEPING	-	.521	-	-	-
53. HAPPY	-	-	-	-	.651
54. WELL	-	-	-	-	.694
55. CLEAR THINKING	-	-	-	-	.588

a

b

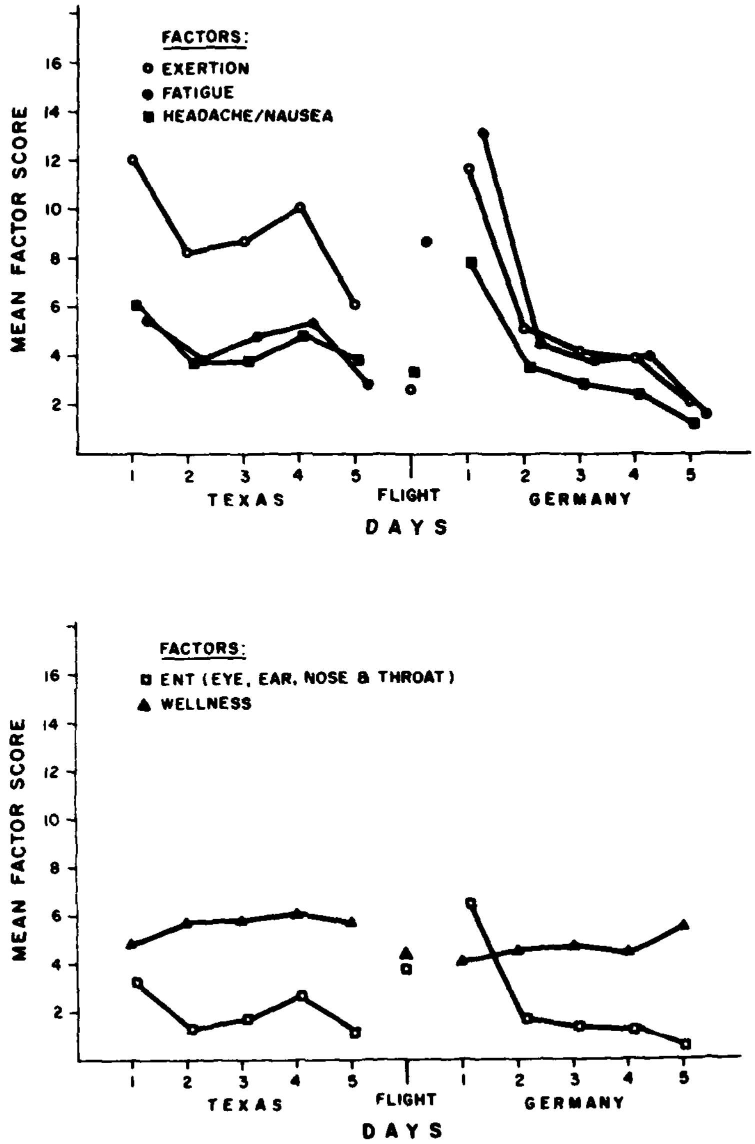


Figure 1a and b. Symptom (Factor) scores on the Environmental Symptom Questionnaire (ESQ) are shown as daily means of 2 administrations/day to 45 subjects (total N = 90) in the 1978 Jet Lag Study.

It was anticipated that post-exercise Exertion scores would be higher than during the sedentary air flight, but that Fatigue scores might be higher during flight and for some time after arrival in Germany. Indeed, Exertion scores were significantly higher on the Texas post-exercise trials 1, 2, 3 and 4, but not on trial 5. In Germany only trial 1 showed significantly high Exertion scores. This suggests some improvement in aerobic fitness as a result of the exercise testing itself, or at least some adaptation to the test regime. In contrast to the Exertion scores, Fatigue scores on trials 2 and 5 in Texas were significantly lower than the control inflight values and again on trials 3, 4, and 5 in Germany but were significantly higher on trial 1 in Germany. This is consistent with the conditions of the study since the men were allowed only a few hours of sleep before being tested on the first day in Germany.

It was anticipated that the EENT score would reflect the common complaints of long distance air travellers, due perhaps to low cabin humidity or pollutants. As predicted, the inflight EENT score is higher than any of Texas values; it rises even higher on the first day after arrival in Germany, then fails to preflight levels. The Headache/Nausea score also showed a spike only on day 1 in Germany. Except for Wellness all factors showed a progressive decrease across trials in Germany. Wellness scores showed no significant changes throughout the study.

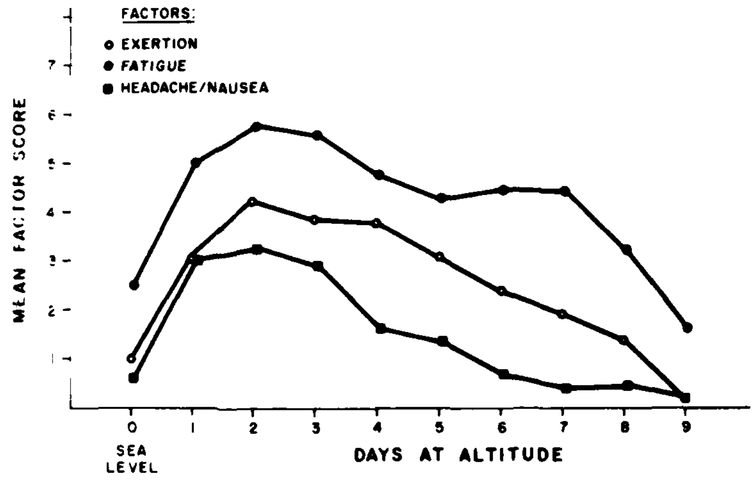
One major advantage of the Jet Lag study was the wide variety of stresses the men were exposed to throughout the study. Since the conditions elicited a variety of symptoms, the changes for finding relationships between symptom items were increased. While the factors which were found may clearly represent the conditions of the study, namely, physical exertion and the fatigue, desynchronization and cabin environment of air travel, they are also relevant to other stresses such as acute mountain sickness. For example, the main symptom clusters of AMS involve shortness of breath, pounding heart, headache, nausea, fatigue and moodiness. Thus, for AMS we would expect factors IV, and I and II, (Headache/Nausea, Exertion and Fatigue), to be the prominant factors respectively. If a group or an individual is suffering from a cold or sinus infection, we would expect Factor III (EENT) to be high and Factor V (Wellness) to be low. Under "normal" conditions only Factor V would be high.

To test these expectations, the resulting factor weights of the factor analysis were applied to the data from a 1978 Pikes Peak study. Seven subjects

completed questionnaires once at sea level before going to Pikes Peak then three times a day for nine days while at the 4300 meters altitude. Since their daily activities varied inconsistently prior to each administration, the three questionnaires per day were combined to give each subject a mean score per day in order to attenuate the activity effects. In the analysis each altitude day's mean scores, for seven subjects, were compared to their sea level scores.

Figure 2a and b display the results of the computed mean factor scores across test trials. All five factors scores showed significant changes ($p < .05$) from sea level values on the first three days at altitude. For the factors of Exertion (I), Fatigue (II), EENT (III) and Headache/Nausea (IV) the peak values were reached on day 2 at altitude while reports of Wellness (V) bottomed out on day 1.

a



b

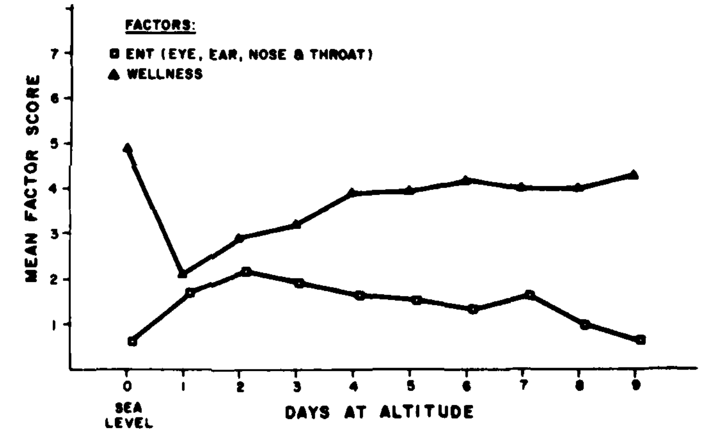


Figure 2a and b. Symptom (Factor) scores on the Environmental Symptom Questionnaire (ESQ) are shown as daily means of 3 administrations/day to 7 subjects (total N = 21) in the 1978 Pikes Peak Study.

Significant increases in Exertion and Fatigue and decreases in Wellness persisted to day 4 at altitude. Headache/Nausea symptoms became insignificant on day 4 and continued to decline thereafter. Significant increases in eye, ear, nose and throat (EENT) symptoms were reported on days 1, 2, 3, 4, 5 and 7 at altitude. Except for Wellness, all factors showed a progressive decline in the later trials, reaching or going below their baseline values.

The differential response of symptoms clusters within and across the two studies reported here conform roughly to exposure conditions and provide constructive validity in a limited sense. In the altitude data the EENT and Wellness scores responded independtly of the other three factors scores which conformed to AMS symptomatology. In contrast, the Exertion scores showed an independence to fatigue, EENT and Headache/Nausea factors in the Jet Lag study.

While the general decline of values across trials in both studies suggests general response changes, perhaps due to motivation and failure to respond to specific questions, there is some indication subjects continued to make discriminating responses. The Wellness scores in both studies did run counter to the other Factors, and the EENT values were particularly independent in the Pikes Peak study. However, some interactions are to be expected. For example, extreme fatigue could very well effect exertion responses while the reverse might not be true. This appears to have occurred in the Jet Lag study. In Texas the Exertion scores were high while the Fatigue scores were low. However, as a result of the transatlantic flight, Fatigue scores became high and subsequent Exertion scores after exercising showed a strong parallel to the Fatigue scores.

The interrelationships between symptom categories across conditions needs to be explored in greater detail in order to avoid confounding influences.

A final comment should be made regarding individual item analysis and Factor Analysis. A number of items on the questionnaire were not utilized in any of the factors extracted. This does not mean that they are unimportant. It means that, for the conditions studied, they were not important. Overuse of Factors scores, exclusive of individual item analysis, can lead to blind spots created by the original study. Certain items are never examined if only Factor scores are used. Therefore, it is recommended that each user of the ESQ also look at items individually in addition to the Factor scores. There are times, for example, that increased reports of diarrhea among test subjects would be

important to an investigator but this is not part of any of the basic Factor scores. Factor scores become more important in small sample studies where individual response errors are magnified. Item clusters attenuate individual response errors. In large sample studies individual item analysis may prove more enlightening.

Further operational testing of the ESQ, along with other survey questionnaires will be conducted in association with USARIEM laboratory and field studies. In addition, surveys will be conducted of selected Army populations in garrison settings and during field exercises in diverse harsh climates.

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2. Lake, D. G., M. B. Miles and R. B. Earle. Measuring Human Behavior. Teachers College Press, 1973.

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4. Nie, N. H., C. H. Hall, J. G. Jenkins, K. Steinbrenner and D. H. Bent. Statistical Package for the Social Sciences, second ed., McGraw-Hill, NY, 1975.

(83041)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OC 6131	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
78 10 01	D. Change	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	041
b. CONTRIBUTING				
c. CONTRIBUTING	CARDS 114f			

11. TITLE (Precede with Security Classification Code)*

(U) Prophylaxis Susceptibility and Predisposing Factors of Cold Injury (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 002300 Biochemistry; 002600 Biology; 003500 Clinical Medicine; 005900 Environmental Biology; 012600 Pharmacology; 012900 Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
10 01	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	5	103
	CURRENT 80	5	87

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* HAMLET, Murray P., D.V.M.

TELEPHONE: 955-2865

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: ROBERTS, Donald E., Ph.D.

NAME: KELLY, John, D.V.M., MAJ, VC DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Cold Injury; (U)Peripheral Blood Flow; (U)CIVD; (U)Thermography; (U)VO_2 max; (U)Hypovolemia

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Total allied casualties due to cold injury in WWI, II and Korea exceeds one million cases. Numerous predisposing factors such as dehydration, shock, level of fitness and fatigue will be studied for their impact on susceptibility. Evidence suggests that racial background, cold experience, smoking habits and home of origin may be important to increased cold sensitivity, and peripheral rewarming response will be studied utilizing infrared thermography and multipoint thermocouples. The impact of physiologic, environmental and anthropometric factors in cold injury susceptibility will be studied. From this research adequate medical screening and preventive training and instruction can be developed to decrease casualties.

24. (U) Multipoint thermocouples and infrared thermography will be used to define the onset of vasoconstriction and vasodilation in normal and clinically identified abnormal individuals. A second study involving heavily exercised fatigued test subjects and/or sleep deprived subjects will define the impact of these stresses on peripheral cooling. A third study involving hypovolemia and shock will be animal modeled to study its effects on total body cooling.

25. (U) 78 10 - 79 09 Continuation of the peripheral temperature regulation protocol awaits arrival of a replacement investigator and completion of soft ware development for computer management of IR Thermograms. Thermograms can now be stored on video disc, analyzed for surface area of given temperatures and reproduced on the CRT. Data analysis of thermographic input is also possible.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 041 Prophylaxia Susceptibility and Predisposing Factors of Cold Injury

Study Title: Thermographic Evaluation of Experimentally Produced Cold Injury of Rabbit Feet

Investigators: John A. Kelly, MAJ, VC, D.V.M. and Murray P. Hamlet, D.V.M.

Background:

Previous research conducted on the thermographic evaluation of experimentally produced frostbite utilized the production of a fourth degree necrotizing lesion (1). In that study, the patterns of skin temperatures, as measured by thermography, enabled the prediction of a line of demarcation and extent of subsequent sloughing early in the course of frostbite injury. After four hours, the thermographs of the individual rabbit paws, showed marked temperature gradients and by 24 hours the thermographic patterns were well defined and clearly depicted the tissue that would slough. Although the main arterial blood supply was still demarcated, there were parallel isotherms running from the lateral border to the medial border at the freeze line. The purpose of this research is to determine the value of thermography as a prognostic tool in differentiating degrees and extent of tissue damage in less severe cold injury.

Progress:

Progress on this protocol has been hampered by mechanical breakdown with the equipment, e.g. initially the autocolor attachment and multi-cool units and presently the video disk memory. The disk does not always record a thermograph on both tracks and it exceeds the upper and lower limit during the erasing process. The process of correcting these problems is in progress.

A program for continuous monitoring of temperatures has been implemented using the numatron temperature acquisition system (2). With this system

the following temperatures can be measured every 30 seconds during the injury phase and the rewarming phase: ambient temperature, deep foot temperature, rectal temperature, ice bath temperature, hot bath temperature, black body temperature and area under the curve.

A thermovision software system utilizing a video disk memory has also been developed to acquire and analyze data from the AGA infrared camera (3). The procedure consists of storing infrared images from the camera on a video disk. The video disk is then connected to the computer through a special interface and the images are acquired from the video disk and stored in the computer. In the process, the data are transformed from analog to digital which enables processing by a digital computer. The program consists of a set of simple commands to the computer. Each command is designed to accomplish one user function.

The system is made up of two main functional areas. The first area is used for data acquisition and calibration functions. The second area is used for the analysis function which will store the calibrations and images; get old pictures and display them; get acquired pictures and allow the investigator to move the cursea around so he can find points in the object or background; builds a file of ranges the investigator chooses; computes percentages of the picture points that fall in these ranges both on the right and left foot; midline picture splitting and the establishment of new high and low temperature boundaries.

A technique for hard copy plotting of time/temperature curves using a Tektronix plotter is being developed by the Information Sciences Branch. Continuation of the protocol will continue when the problem with the video disk is corrected.

At the end of the experiment it is hoped that a correlation between the time/temperature curve representing actual degree of injury and the thermographs representing heat loss patterns and the 35 mm photographs representing clinical injury can be made so clinicians would have a prognostic tool for early determination of severity of tissue damage and research would have a reproducible animal model to determine effectiveness of present and experimental treatments.

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3. Marseglia, J. and D. Winkler. Users Guide to the AGA Thermovision Software System, USARIEM, 1979.

(83042)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY				1. AGENCY ACCESSION*	2. DATE OF SUMMARY*		REPORT CONTROL SYMBOL
				DA OB 6144	79 10 01		DD-DR&E(AR)636
3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
78 10 01	D. Change	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT
10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER		TASK AREA NUMBER	WORK UNIT NUMBER		
a. PRIMARY	6.27.77.A	3E162777A845		00	042		
b. CONTRIBUTING							
c. XXXXXX	CARDS 114f						

11. TITLE (Precede with Security Classification Code)*

(U) Models of Heat Disabilities: Treatment and Diagnosis (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

005900 Environmental Biology; 003500 Clinical Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	13	270
	CURRENT 80	6	241

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* MAGER, Milton, Ph.D.

TELEPHONE: 955-2871

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: HUBBARD, Roger, Ph.D.

NAME: FRANCESCONI, Ralph P., Ph.D. DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Disabilities; (U)Military Heat Stress; (U)Pathology Model; (U)Physiology; (U)Biochemistry; (U)Behavior; (U)Tolerance; (U)Heat

23. TECHNICAL OBJECTIVE.* 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) The use of model systems to develop new or modified forms of treatments or diagnosis for the various disabilities, injuries and performance decrements associated with military operations in the heat.

24. (U) A variety of agents will be evaluated for their efficacy in reducing core temperature, decreasing the pathological effects of hyperthermia, increasing performance, or alleviating the symptomatology of heat illness among humans or animals acutely exposed to high environmental temperatures or work regimens. Additionally, a variety of clinical and physiological parameters will be evaluated for their usefulness in the early diagnosis of heat illnesses, and to characterize in animals and humans those who have experienced or are susceptible to heat related injury.

25. (U) 78 10 - 79 We have established that the glucose analogue 5-thio-D-glucose (5-TG) is extremely effective in inducing extreme hypothermia in both mice and rats concomitant with marked hyperglycemia with plasma glucose levels as high as 480 mg%. Mechanistically, the hypothermic response with 5-TG, seems to be the result of central and peripheral glucopenia. The hypothermia is exacerbated by colder temperatures, food deprivation, and increased doses. As a separate study we are testing whether improved heat tolerance and resistance to heatstroke can be achieved in rats by increased cardiovascular efficiency through the rapid expansion of plasma volume by hyperoncotic albumin. The 18-22% expansion of plasma volume following i.v. albumin injection before heating prevented the 27% decrease in plasma volume in controls at 80 min post heating. The volume expansion of albumin treated rats appeared to lower (-25%) the total heat exposure (degree.minutes) during both the heating and cooling phases of the experiment.

*Available to contractors upon originator's approval

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 042 Models of Heat Disabilities: Treatment and Diagnosis

Study Title: Investigations on New Thermoregulatory Agents

Investigators: Ralph P. Francesconi, Ph.D. and Milton Mager, Ph.D.

Introduction:

For many years we have maintained an active research interest in the discovery and utilization of pharmacologic agents which are efficacious thermoregulatory substances in laboratory animals. Our rationale has been that new information on such thermoregulatory agents and their effects could be useful in the discovery of innovative techniques to manipulate body temperature. For example, compounds that are effective in producing hypothermic responses could be used to reduce the physiological cost of work in the heat, to decrease body temperature in patients that might have been affected by heat injury, or even to reduce the rate of increase in body temperature while working in the heat.

One of our continuing research efforts has been directed toward understanding the comparative thermoregulatory effects of compounds which affect glucose metabolism both centrally and peripherally. We have discovered that the administration of 2-deoxy-D-glucose (2-DG), insulin, or norepinephrine will evoke significant decreases in both rectal temperature (Tre) and oxygen consumption in several species (1-3). We concluded that the observed hypothermia was caused by central nervous system glucopenia which is accompanied by circulatory hyperglycemia and decreased peripheral heat production.

Recently, Kim and co-workers (4) demonstrated that the glucose analogue, 5-thio-D-glucose (5-TG), was effective in killing cancer cells in vitro when used in combination with hypoxic and hyperthermic (41°C) conditions. They concluded that 5-TG may be interfering with the normal glycolytic process, since earlier Chen and Whistler (5) had demonstrated that phosphorylated intermediates of 5-TG acted as competitive inhibitors of glucose metabolism.

As a result of our interest in the metabolic inhibition and concomitant thermoregulatory effects of analogues of D-glucose, we hypothesized that both

centrally and peripherally administered 5-TG would significantly compromise heat production in laboratory animals. We proposed that by quantitating these decrements under various environmental conditions, these supplementary data would be useful in elucidating the relationship between body temperature and glucose metabolism.

Progress:

In these preliminary experiments adult, male mice (28-35 g) were housed singly in windowless rooms with automatically controlled fluorescent lights (on, 0600-1800 h) and an environmental temperature of $22 \pm 1^{o}C$. Rectal temperature (Tre) were monitored by inserting a thermistor probe to a depth of 2 cm; for exposure to other environmental temperatures the mice were quickly removed either to a constant temperature, walk-in cold room ($4^{o} \pm 1^{o}C$) or a large stainless steel chamber ($35^{o} \pm 1^{o}C$). For intracerebroventricular (ICV) injections the dosage volume was held constant at 0.02 ml, and the site of the injection was determined after the description of Brittain (6). Control mice were ordinarily injected equivolumetrically with appropriate concentrations of D-glucose. Blood was collected by cardiac puncture and the plasma rapidly separated ($4^{o}C$, 4000 rpm) and frozen ($-30^{o}C$) for subsequent analysis.

The results depicted in Figures 1-3 demonstrate the effects of ICV administration of increasing dosages of 5-TG on the Tre of mice exposed to three environmental temperatures.

It can be observed in Figure 1 that by 15 min following the administration of 37.5 µg of 5-TG, there was a significant ($p < .02$) hypothermic response which is dose-dependent. At the two lower concentrations the maximal response is observed at 15 and 30 min with Tre increasing by 45 min after administration. However, the response to the highest dosage administered (100 µg) was highly significant ($p < .001$) by 15 min and Tre continued to drop until by 90 min 3 of the animals have Tre below $20^{o}C$, and these animals actually succumbed to the deep hypothermia before 120 min thus terminating the experiment.

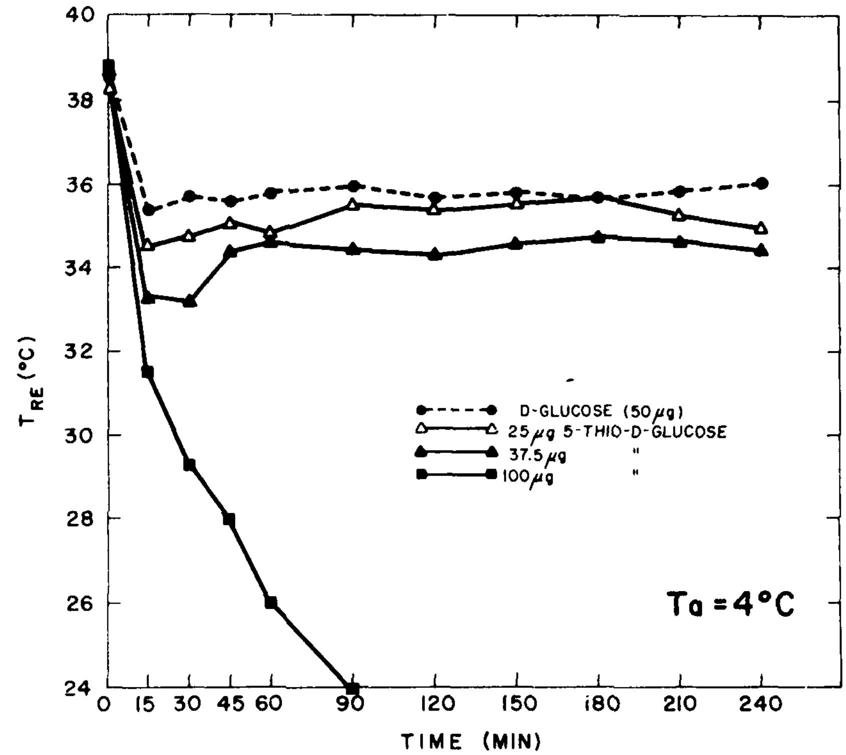

Figure 1. Effects of ICV administration of various concentrations of 5-TG at an ambient temperature of 4°C. Each point represents the mean value for 5 mice in each group. Control animals were treated ICV with an equivalent dosage and volume (50 µg/0.02 ml) of D-glucose in sterile, non-pyrogenic 0.9% NaCl.

It can be observed in Figure 2 that analogous, but less intense, responses are observed. For example, 30 min following the ICV administration of 5-TG, a dosage level of 50 µg has effected a highly significant ($p < .001$) hypothermic response, and higher dosages elicited more pronounced decrements in Tre.

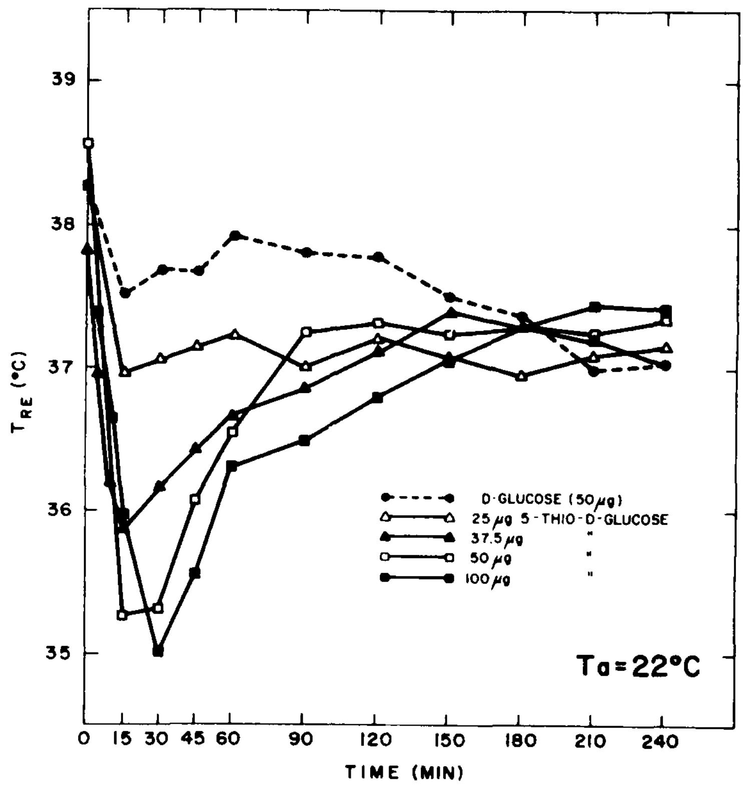

Figure 2. Effects of ICV administration of various concentrations of 5-TG at an ambient temperature of 22°C. Each point represents the mean value for 5 mice in each group.

At 35°C (Figure 3) the dose-response pattern disappears with significant ($p < .05$) decrements noted for only the 50 µg dosage at 15, 90 and 120 min post-injection. Thus, decreases in Tre as a result of ICV administration of 5-TG were consistently observed in these experiments. Under cold ambient conditions the hypothermia resulted in the death of several animals at a dosage of 100 µg, while under more moderate conditions (22°C) Tre returned to normal levels usually by 60 min.

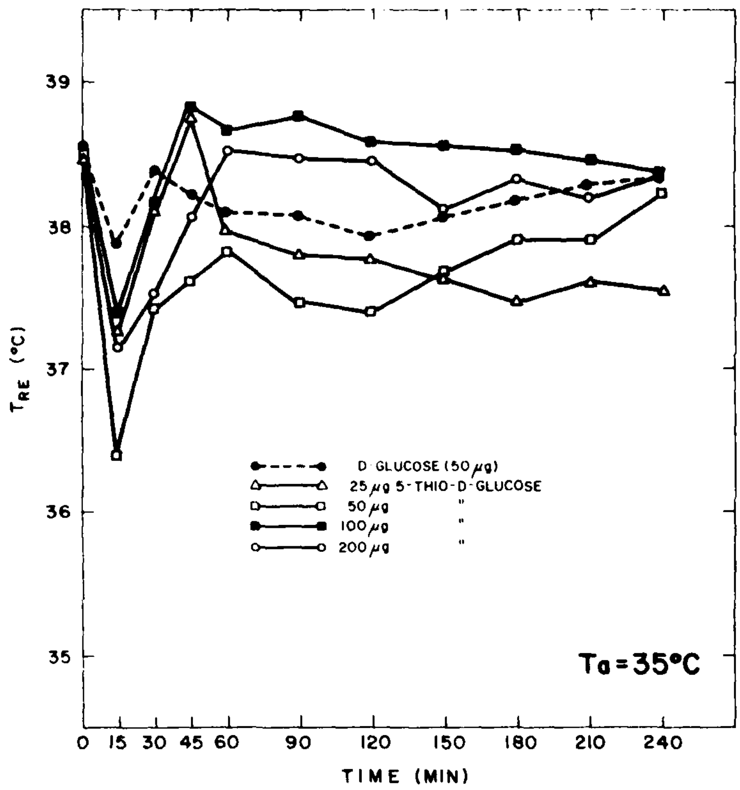

Figure 3. Effects of ICV administration of various concentrations of 5-TG at an ambient temperature of 35°C; each point represents the mean value for 5 animals/group.

The results of IP administration of 5-TG are depicted in Figures 4-6 for the three environmental temperatures studied; while once again dose-dependent decrements in Tre were observed, a noteworthy anomaly occurred. Under each of the three ambient conditions the lower dosages of 5-TG effected significant elevations in Tre when compared with controls. Thus, at 4°C (Figure 4) the 5 mg dosage of 5-TG resulted in a significant increase in Tre ($p < .025$) after 45 min. Note, however, that a 4°C the highest dose tested (20 mg) resulted in a marked hypothermia which again resulted in the death of several of the experimental animals.

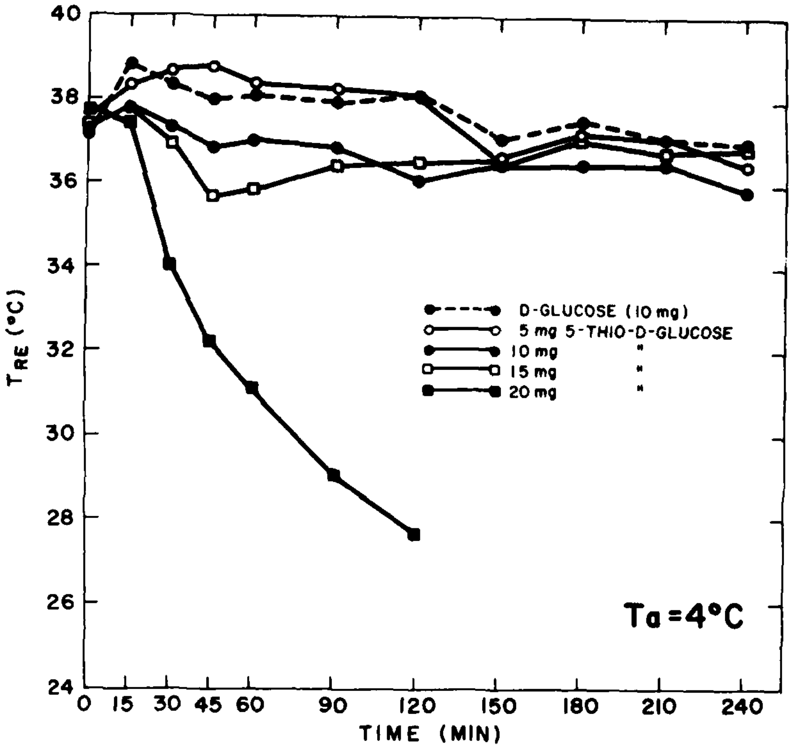

Figure 4. Effects of intraperitoneal (IP) injection of various concentrations of 5-TG at an ambient temperature of $4^{o}C$. Each point represents the mean value of 5 animals/group except the 15 mg dosage where n=4. Control animals were also treated IP with 10 mg D-glucose/0.1 ml 0.9% NaCl.

In Figure 5 there is again observed at a generalized hypothermic response which is dose-dependent for the three higher concentrations. However, it should be noted that for the lower concentrations (10 mg) significant hyperthermia occurs at 90, 120, 150, and 240 min following administration of the drug. At $35^{o}C$ (Figure 6) 10 mg of 5-TG elicited a significant increment in Tre at 60 min ($p < .02$). Thus, the consistent pattern of these low-dosage increments at the three environmental temperatures appears to be a real physiological effect and not an artifact.

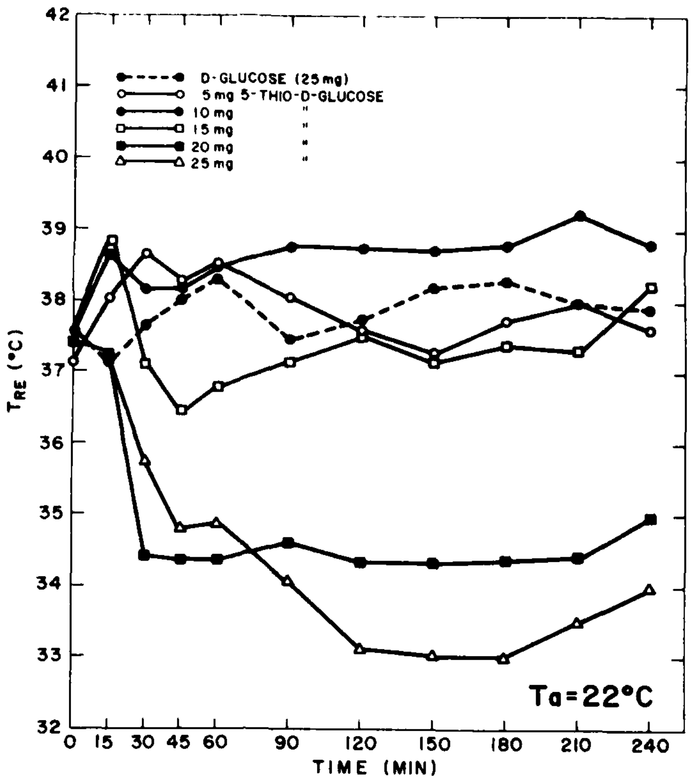

Figure 5. Effects of IP injection of various concentrations of 5-TG at an ambient temperature of 22°C.

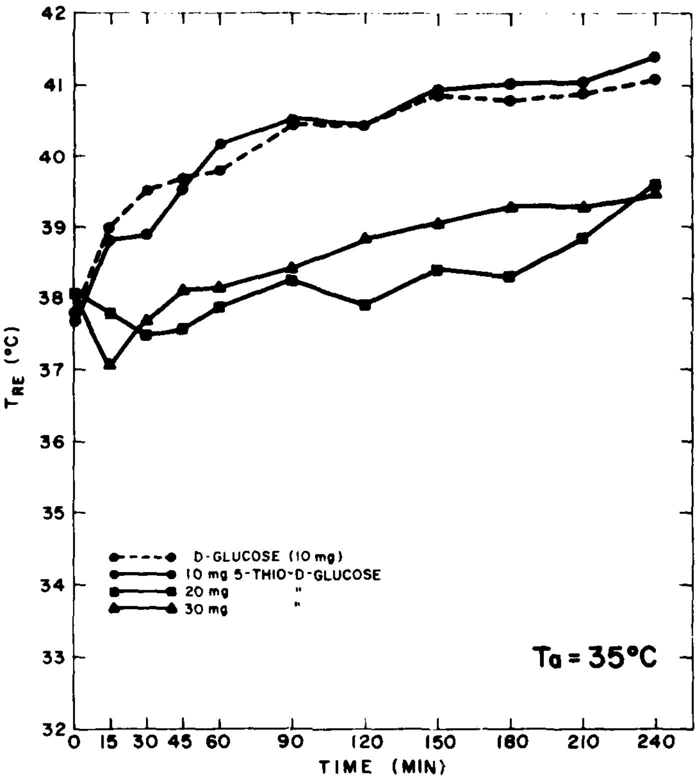

Figure 6. Effects of 5-TG administration on the Tre responses of mice at an ambient temperature of 35°C.

Figure 7 demonstrates clearly the effects of prior nutritional status of the mice on the intensity of the response to an IP injection of 20 mg 5-TG at 4°C. Animals which were food-deprived for 18 h had significantly greater hypothermic responses at 30 min ($p < .001$) and 45 min ($p < .005$) than fed controls. Figure 8 indicates the intense hyperglycemic responses which occur as a result of IP administration of 20 mg 5-TG in cold-exposed mice. Control animals were injected with 0.9% NaCl and sacrificed after 60 min with a minimal Tre of 36.21°C; 5-TG treated animals were sacrificed after 30-60 min with Tre ranging from 27.5° - 35.6°C. Plasma glucose levels were significantly increased ($p < .001$) in the 5-TG treated mice. When mice were food-deprived and treated with equivalent doses of 5-TG, plasma glucose levels were again significantly

higher ($p < .001$) than saline-treated controls. However, it is important to note also that food-deprived, 5-TG treated animals had significantly ($p < .02$) lower glucose levels than fed, 5-TG treated mice.

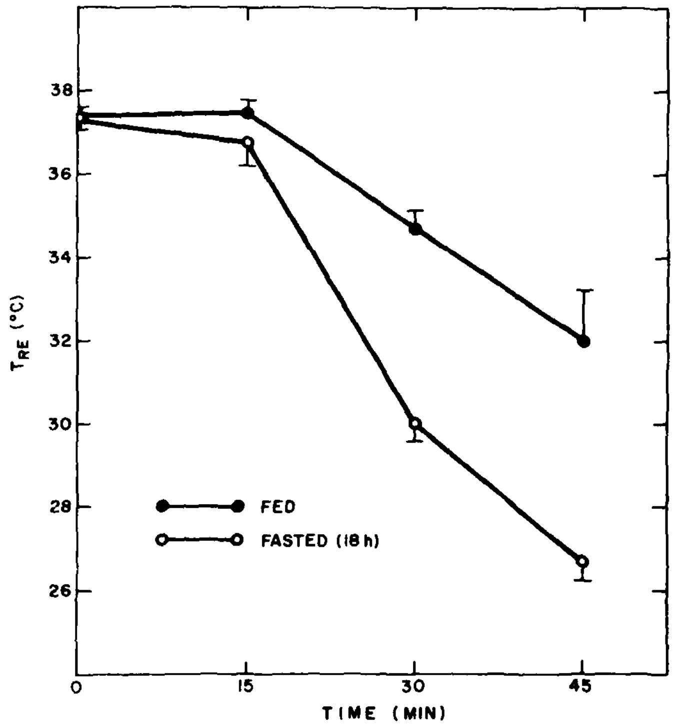

Figure 7. Effects of 5-TG IP (20 mg/0.1 ml 0.9% NaCl) on the Tre of 2 groups of mice (n=4/group). The closed circles represent data for animals which were allowed food ad lib until the time when the experiment was begun while the open circles represent the responses of animals which were food-deprived for 18 h prior to the start of the experiment. Mean values ± SEM are depicted.

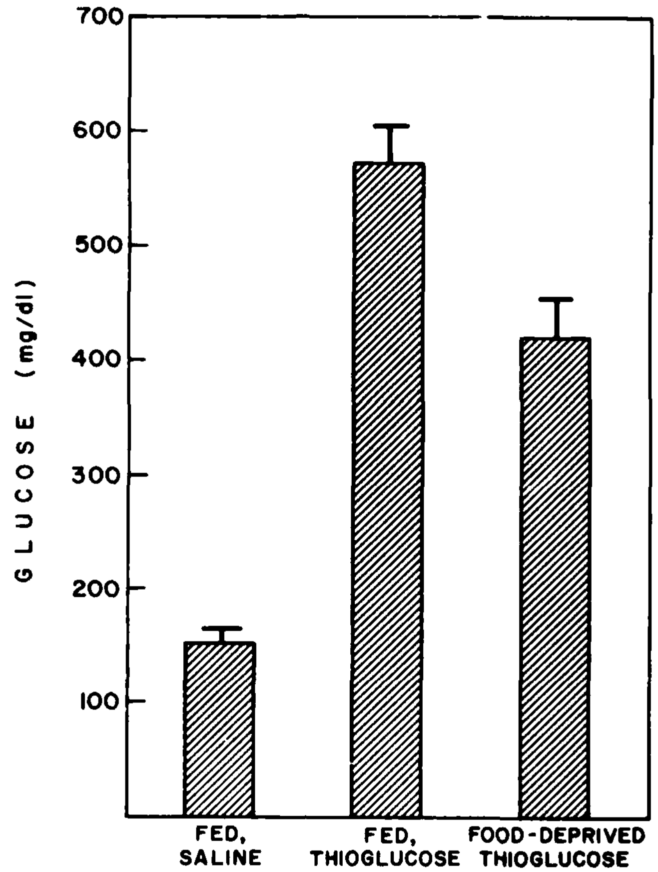

Figure 8. Effects of 5-TG IP (20 mg/0.1 ml 0.9% NaCl) on plasma glucose levels of mice kept at 4^{o}C. The bar on the left side of the figure represents the mean value (+ SEM) for a group of fed, control animals (n=5) injected with 0.1 ml saline. The middle bar represents the mean plasma glucose level (+ SEM) for a group of fed mice (n=7) injected with 20 mg 5-TG/animal. The bar on the right side depicts the mean value (+ SEM) of plasma glucose for mice (n=4) treated with 20 mg 5-TG/mouse IP and food-deprived for 18 h. Blood samples were taken by cardiac puncture 30-60 min after injection of 5-TG.

The results of the present experiments demonstrate clearly the role of glucose metabolism in the regulation of body temperature, particularly for thermogenesis upon acute exposure to cold ambient conditions. These results are indicative of the extreme thermoregulatory sensitivity of these animals to the 5-

TG. Further, this sensitivity probably results from intracellular glucopenia occurring both centrally at the sites of temperature regulation and peripherally at the sites of heat production. The initial rapid hyperthermia consistently occurring subsequent to IP administration of low doses of 5-TG are probably peripheral in nature, and associated with heat loss mechanisms or rapid glycogenolysis in the absence of sufficient accumulation of phosphorylated 5-TG intermediates to inhibit anaerobic catabolism. Observations from these experiments have also enabled us to utilize 5-TG to induce hypothermia in rats before exercising these animals in the heat. In another section of this report we have demonstrated the efficacy of this preinduced hypothermia to increase the endurance capacity of these animals.

We anticipate that research on the efficacy of pharmacologic agents to affect thermoregulatory responses will be continued in the Heat Research Division. We believe that studies on the mechanisms of temperature control under various environmental and exercise conditions are necessary to elucidate the pathways and mechanisms of heat production and dissipation, and that these studies may ultimately lead to new treatment regimens to decrease the morbidity of heat injury.

Presentations:

Francesconi, R. P. and M. Mager. Heat- and exercise-induced hyperthermia: Effects on high energy phosphates (HEP), creatine phosphokinase (CPK), and adenosine triphosphatase (ATPase). Fed. Proc. 38:1052, 1979.

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(83043)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OB 6146	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	D. Change	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	043
b. CONTRIBUTING				
c. XXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)*
(U) Physical Fitness Requirements, Evaluation and Job Performance in the Army (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*
012900 Physiology; 012500 Personnel Training & Evaluation

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT GRANT
a. DATES/EFFECTIVE: NOT APPLICABLE EXPIRATION:
b. NUMBER:*
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18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	15	312
	CURRENT 80	6	168

19. RESPONSIBLE DOD ORGANIZATION
NAME:* USA RSCH INST OF ENV MED
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NAME:* USA RSCH INST OF ENV MED
ADDRESS:* Natick, MA 01760
PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)
NAME:* VOGEL, James A., Ph.D.
TELEPHONE: 955-2800
SOCIAL SECURITY ACCOUNT NUMBER:
ASSOCIATE INVESTIGATORS
NAME: PATTON, John, Ph.D.
NAME: DA

21. GENERAL USE
Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Physical Fitness; (U)Muscle Strength; (U)Aerobic Fitness; (U)Fitness Evaluation; (U)Job Performance; (U)Physical Training; (U)Job Tasks

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Physical fitness training programs in the Army should be based on requirements for job performance, health and morale. Fitness standards therefore should be scientifically linked to job (MOS) demands. MOS entry qualification should include a fitness screening test at the AFEES. Such policies will require that demands of job performance be better identified.

24. (U) Specific areas of study will include: (1) Identification and physiological measurements of MOS task demands, (2) Conversion of task demands into physical fitness standards, (3) Development of fitness tests for entry and MOS assignment, (4) Development of relationships between fitness measures and job performance criteria.

25. (U) 78 10 - 79 09 (1) In a combined effort with DA-TRADOC, representative tasks for measurement have been identified for five clusters of MOSs representing all enlisted jobs. Physiological cost analysis of these tasks is partially completed. (2) Furthe fitness screening test for the AFEES has been planned.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 043 Physical Fitness Requirements, Evaluation and Job Performance in the US Army

Study Title: Development of MOS fitness standards and an AFEES fitness classification system for MOS assignment qualification (PH-2-79)

Investigators: James A. Vogel, Ph.D., John F. Patton, III, Ph.D., James E. Wright, CPT, MSC, Ph.D. and Dan S. Sharp, CPT, MC, M.D.

Background:

For the past two years, this Division has been working under a tasking from DA-DCSPER to: (a) revise the Army physical training program so that fitness standards are based on MOS requirements and (b) to develop a fitness test battery for Armed Forces Entrance Examination Stations (AFEES) to be used for MOS assignment qualification. These MOS entrance standards at the AFEES will be based on the MOS training standards developed under tasking (a). Research during the past two years has led to (a) MOS categorization according to estimated strength and stamina demands, (b) establishment of job demand criteria, (c) selection of MOS tasks for evaluation upon which to base standards, (d) measurement of physiological cost of one group of MOSs, (e) development of a number of possible fitness test battery items and (f) completion of an initial evaluation of these items.

Progress:

During the past year a major study was initiated which is expected to complete the data collection for both taskings and lead to final recommendations on both the establishment of standards as well as a testing system for the AFEES. Specifically, the study was designed to: (a) measure the aerobic energy costs of the most demanding tasks representing the five MOS clusters (see last

years report) and (b) relate various measures of muscle strength to the criterion tasks of maximum safe lift and 55 and 95 lb lift and carry events. The latter will be used to select strength test items for the AFEES battery. In addition, the exercise heart rate stepping test was further evaluated as an AFEES test of aerobic power.

Data collection commenced on 17 September 1979 on soldiers from the 24th Infantry Division, Ft. Stewart, GA and will not be complete until late October 1979. Thus, data collection and tabulation is not complete at this time. Data will be collected from over 100 MOSs representing all five MOS clusters on a total of approximately 300 personnel.

Presentation:

Vogel, J. A. Fitness and work capacity of women: military service. Symposium on "Fitness and Work Capacity with Special Reference to Women and Minorities", American College of Sports Medicine, 25 May 1979, Honolulu.

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 043 Physical Fitness Requirements Evaluation and Job Performance in the US Army

Study Title: Interrelationships of isometric, isokinetic and anisometric strength testing

Investigators: James E. Wright, CPT, MSC, Ph.D. and Joseph J. Knapik, SP6

Background:

Muscle strength is a valid and reliable theoretical construct which has impact on virtually all areas of physical work, training, testing and rehabilitation in both military and civilian environments. Although it is not yet known to what extent muscle strength is important in the total fitness of today's soldier, preliminary MOS task analyses conducted jointly by TRADOC, USAIS and USARIEM suggests that muscle strength may be a limiting (most physically demanding) performance factor in 25-30% of Army MOSs.

The extent to which physical performance in the military can be predicted from relatively simple tests of muscular strength is currently of considerable importance in light of the DA tasked efforts of USARIEM to develop a fitness test battery. The assumption has been made that a specific battery of muscle strength (and stamina) tests can be developed that can make possible more effective personnel acquisition and utilization. For example, in a test battery developed by USARIEM for use in the AFEES stations, the static (isometric) strength of three major muscle groups were assessed. Implicit in this test is the assumption that static strength measures can be valid predictors of dynamic efforts.

However, further research is necessary to clarify the interrelationship between muscular strength measured in static and dynamic modes. The currently available published experimental data show a general variability and ambiguity of results that makes accurate prediction of one type of strength from another difficult or impossible. There has been a lack of standardization of

instruments, motivational techniques, criterion measures and instruction. This is especially true with regard to the lack of control of synkinetic movement patterns in many studies. Further complicating the situation is the fact that many work activities consist of variable fractions of static and dynamic work.

Human muscular strength, in a broad sense, refers to the ability of a muscle or muscle group to exert a maximal force in a single voluntary effort. This force, reflecting some ability of the muscle to convert chemical energy to mechanical force (tension) can be quantified as a torque (rotary force at a specific distance from the involved joint to the outside point of resistance or load). Of the three testing modes currently available for assessing muscular strength, one (isometric) holds muscle length constant, another (isokinetic) holds the velocity of the contraction constant and one (anisometric, conventionally called isotonic) holds resistance constant while allowing muscle length and contractile velocity to vary in a ballistic manner throughout the range of motion.

Voluntary limb movement is the simple and direct result of a physical (muscular) force. That absolute force development is significantly influenced by the type of measurement employed has been known since 1938 (9). However, the question posed here is whether the different modes of testing are all measuring the same phenomena ("strength"). The literature reveals two schools of thought. One, presented by Henry and coworkers (3,6,7,8), reports poor to moderate relationships between "strength in action" and isometric strength and concludes that "strength" is highly task specific due to basic differences in physics and the physiology of isometric and dynamic contractions (8). These results suggest that the specificity of movement and neuromuscular coordination involved in the different tests preclude prediction of performance in one mode from force capacities measured in another mode. However, several other studies (1,2,10) demonstrate that high correlations are possible between strength testing modes although no theoretical structure currently exists to explain these results.

A close examination of the above cited studies suggests that the velocity at which the contraction is performed may be a critical variable. Many of the studies by Henry and coworkers (3,8) compared a zero velocity movement (isometric) to a high velocity, ballistic type performance. The latter was usually a measurement of a movement time or force calculated from physical equations. The studies that have found a high relationship among testing modes (1,2) have compared two or more zero velocity movements or relatively slow movements.

It thus seems reasonable to hypothesize that a high relationship should be expected between the torque exerted by a subject isometrically, anisometrically and in a low velocity isokinetic mode. A lower relationship would be expected between these three testing modes and high velocity isokinetic torque. This study was designed to test these hypotheses.

Progress:

Ten males and ten female subjects were studied. Four muscle groups were tested: the knee extensors (KE), knee flexors (KF), elbow extensors (EE) and elbow flexors (EF). Maximum voluntary contractions (MVC) were elicited isokinetically, isometrically and anisometrically for each muscle group. Three isokinetic contractions were performed at each of three angular velocities: 30°/sec, 90°/sec and 180°/sec. For the isometric testing contractions were performed at every 10° of joint angle in the available range of motion. For the KE and KF this was from 80° to 170° (10 angles) and for the EE and EF from 40° to 170° (14 angles). Anisometric testing consisted of a one repetition maximum (1 RM) procedure following the DeLorme technique (4,5). In the final test session an isokinetic endurance bout was performed. Data collection has been completed but analyses are still in progress.

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(83045)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OB 6146	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	D. Change	U	U	NA	NL	☐ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	045
b. CONTRIBUTING				
c. ~~CONTRIBUTING~~	CARDS 114f			

11. TITLE (Precede with Security Classification Code)*

(U) Treatment of Cold Injury (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 002300 Biochemistry; 002600 Biology; 012900 Physiology; 005400 Environmental Biology; 003500 Clinical Medicine

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	3	124
	CURRENT 80	2	70

19. RESPONSIBLE DOD ORGANIZATION

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ASSOCIATE INVESTIGATORS

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21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code)

(U)Cold Injury; (U)Hypothermia; (U)Fasciotomy; (U)Vasodilation; (U)Angiography

23. TECHNICAL OBJECTIVE.* 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Although cold injury is of little clinical significance in the civilian community, it has had serious impact on every Army that has attempted to fight in the cold. Hospitilization times for Korea and Second World War were 37 and 57 days respectively. Amputation and permanent loss of function and death are routine sequella. Current knowledge suggests that increased blood flow and internal methods of rewarming and surgical approaches to frostbite may decrease the hospitalization time and increase tissue salvage.

24. (U) An intervenous frostbite treatment solution was developed and utilized during the Korean conflict. Animal studies will be done with modifications of this formula to include better vasodilators to determine the effect on long-term tissue survival. Internal methods of rewarming hypothermic animals will be studied for the effects on physiologic parameters that affect survival. Studies on cellular enzyme release after different degree of cold injury will be done. The role of platelet aggregation and release of fibrin split products will be studied.

25. (U) 78 10 - 79 09 Pilot studies indicating differential release of enzymes indicative of cell destruction (CPK and acid phosphatase) supports the necessity of a more thorough study on venous effluent from a cold injury extremity. Protocols for fibrinolysis, cellular enzymes and blood gases have been written, submitted and are underway. The study on an intravenous treatment solution for cold injury utilizing the Korean formula and the new combination has been submitted and is underway.

*Available to contractors upon originator's approval.

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 045 Treatment of Cold Injury

Study Title: Evaluation of Therapeutic Intravenous Frostbite Solution

Investigators: John A. Kelly, MAJ, VC, D.V.M., Murray P. Hamlet, D.V.M. and John C. Donovan, CPT, VC, D.V.M.

Background:

Intravenous frostbite solution was described in a report of the cold injury research team Medical Research and Development Board, Office of The Surgeon General, Department of the Army (20 March 1951) (1). The mission of this team was to study the various types of cold injury occurring in the Korean theater of operations and to report the procedures found most effective in evaluation, treatment and rehabilitation of cold injury casualties. This research is concerned with use of intravenous frostbite solution recommended as treatment for frostbite casualties by this team. On the teams visit to the cold injury treatment center, (21 Feb 51-58 Feb 51), they discovered that an intravenous frostbite solution was recommended as part of the treatment prior to and after arrival at the treatment center. Later the use of this solution was put in a command directive dealing with cold injury problems in Korea. The formula and its recommended administration were as follows for 2nd and 3rd degree involvement:

12cc ethyl alcohol

250mg procaine hydrochloride

5% glucose in water to make 250cc

1. For frostbite
2. Dosage: contents of this flask (250cc), repeated every six hours for several days.
3. Instructions:
   a. Start treatment as early as possible after each diagnosis
   b. For frostbite cases without other wounds 100mg heparin will be added to each 250cc of solution prior to the administration (2).

4. Caution:

a. Use only the 23-gauge needle provided with the set.

b. In doubtful cases heparin will be used only at the discretion of the local medical officer.

There is nothing in the literature on how this formula was derived, nor is there any record of its actual results as a treatment. This study will try to determine this solutions therapeutic effect.

Progress:

This protocol was presented to the Animal Use Committee on 27 Sep 79 and pending its approval and depending on the outcome of the equipment problem on work study 041 Thermographic Evaluation of Experimentally Produced Cold Injury of Rabbit Feet, work will begin. It was hoped that the thermographic evaluation protocol would be finished so that a more accurate reproducible animal model would be available to determine the effectiveness of this treatment.

Work at this laboratory and elsewhere indicates that there are two major injuries associated with frostbite (3.4). The first is the physical effect of the ice crystal formation within the tissue and the second is a microvascular stasis that occurs within a short time after the thawing procedure (3,5,6,7,8). The subsequent cessation of nutrive flow contributes substantially to the overall destructive process of frostbite necrosis (9). It is suspected that the therapeutic value of intravenous frostbite solution lies within the vasodilatory property of alcohol and procaine and the anticoagulant effect of the heparin promoting microcirculation. This study will be undertaken to see what degree of therapeutic results can be achieved by comparing the results of the treated rabbits with the untreated rabbits.

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(83046)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OB 6149	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	D. Change	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	046
b. CONTRIBUTING				
c. ~~CONTRIBUTING~~ XXXXXX	CARDS 114f			

11. TITLE (Precede with Security Classification Code)* (U)Prevention of Military Environmental Medical Casualties by Epidemiologic Research and Information Dissemination (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS* 012900 Physiology; 013400 Psychology; 022400 Bioengineering; 013300 Protective Equipment; 016200 Stress Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
74 07	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	2.5	72
	CURRENT 80	2.5	76

19. RESPONSIBLE DOD ORGANIZATION

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SOCIAL SECURITY ACCOUNT NUMBER:

21. GENERAL USE

Foreign Intelligence Not Considered

ASSOCIATE INVESTIGATORS

NAME: GOLDMAN, Ralph F., Ph.D.

NAME: VOGEL, James A., Ph.D. DA

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Military Operations; (U)Performance Limits; (U)Military Tactics; (U)Environmental Medicine

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Identify environmental medicine problems in Army units as research requirements. Maintain dialogue with DA staff and line to (a) communicate research results to potential users, (b) provide assistance and resolve difficulties in interpreting and applying research, (c) identify unsolved problems. Provide a continuing source of identified, in-depth expertise on the impact of physiological and psychological status, military clothing and equipment, natural and crew compartment environments, high terrestrial elevations, and physical fitness, on the soldier's health and mission capability.

24. (U) Maintain direct liaison with DA schools, line and staff units by visits, conferences, and correspondence. Maintain reference files on climate, clothing, and equipment, and physical and physiological differences among military populations, as a base for predicting environmental impact and mission capability. Assist in preparation of training films, TB MEDs, FMs, and other doctrine; provide consultation to units planning military operations under stressful conditions; assist with doctrine for physical training and/or acclimatization.

25 (U) 78 10 - 79 09 Predeployment briefings of military units concerning prophylaxis and therapy for the climatic stress of heat and cold have continued and presentation at civilian institutions have furthered transfer of relevant information between USARIEM and civilian organizations involved in common research efforts. Similarly, briefs and consultations with major Army commands, e.g., TRADOC, FORSCOM, have provided expertise and recommendations concerning military problems related to fitness and readiness. In addition, a Surgeon's Conference attended by Army and Marine Division, Corps and Brigade Surgeons was planned, organized and conducted.

*Available to contractors upon originator's approval

DD FORM 1498, 1 MAR 68 — PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 046 Prevention of Military Environmental Casualties by Epidemiologic Research and Information Dissemination (22)

Study Title: Prevention of Military Environmental Casualties by Epidemiologic Research and Information Dissemination (22)

Investigator: Harry G. Dangerfield, Colonel MC, Research Staff, USARIEM

Background:

The research efforts of USARIEM are directed toward insuring that line components of US Forces can accomplish their missions despite the impact of climatic stress. One aspect of this work is comprised of a highly competent and talented, multi-disciplinary scientific staff providing most current and accurate information emphasizing the prevention of casualties due to environmental extremes.

Another equally important effort is translation of new information, comments and recommendations to those most directly concerned, i.e. US active duty, Reserve and National Guard units. To accomplish this, efforts are directed toward: 1) predeployment briefings of military units; 2) briefings for major Army Commands and Army Staff, e.g. TRADOC, FORSCOM, HSC, DCSPER, to provide expertise and recommendations for military problems, related to physical fitness, training and readiness; 3) consultation with Reserve and National Guard units and, 4) consultation with civilian research and academic institutions to transfer relevant and current research data and information.

Progress:

Attempts to effect current and updated mission related technology transfer to military users have continued. Consultations requested of the USARIEM staff during FY 79 are listed in Appendix D and the briefings and lectures given are detailed in Appendices E and F.

Of special note was a conference sponsored by USARIEM in December 1978

for the Surgeons of Army, Marine, and National Guard units. The organizations represented at the conference are shown in Table 1. Its purpose was to examine and review the pathophysiological consequences of climatic stress (heat, cold and high terrestrial altitude) upon the operational capability of individual and units to perform their mission. An outline of the material presented is given in Appendix I.

TABLE 1

Organizations Represented at the USARIEM Division Surgeon Conference

HEADQUARTER/STAFF ELEMENTS	CORPS	DIVISIONS	BRIGADES
USAMRDC	III	1st Infantry (MECH)	1st Marine
HQ, USMC	V	3d Armored	172d Light Infantry
JFK Center for Special Warfare	VII	3d Infantry	193d Light Infantry
5th SFG (ABN)		3d Marine (REIN) FMF	194th Armored
OTSG, USMIIA		5th Infantry (MECH)	
FORSCOM		7th Infantry	
		8th Infantry	
		9th Infantry	
		24th Infantry	
		25th Infantry	
		26th Massachusetts	
		49th Texas	
		82d Airborne	
		101st Airborne	

(83047)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
	DA OB 6147	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	D. Change	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	047
b. CONTRIBUTING				
c. ~~XXXXXX~~	CARDS 114f			

11. TITLE (Precede with Security Classification Code)* (U)Improvement of Physical Fitness Training and Prevention of Injuries Related to Training (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012900 Physiology; 012500 Personnel Training & Evaluation

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	1.9	150
	CURRENT 80	1.5	117

19. RESPONSIBLE DOD ORGANIZATION

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21. GENERAL USE

Foreign Intelligence Not Considered

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NAME: 955-2878 DA

22. KEYWORDS (Precede EACH with Security Classification Code) (U)US Military Academy; (U)Physical Fitness; (U)Aerobic Power; (U)Psychological Inventories; (U)Submaximal Workload

23. TECHNICAL OBJECTIVE.* 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Army physical fitness training doctrine is based largely on outdated information and has been slow in adopting new scientific concepts. Physical training in the Army could be made more effective and efficient by appropriate research to meet the Army's needs with this new knowledge and obtain new information in specific areas relevant to the Army (women, older age) where information is lacking.

24. (U) Specific studies will include: (1) Determine the optimum mode, frequency, duration and intensity of training for different applications or needs; (2) Identify differences between men and women, if any, in the qualitative or quantitative respnse to training; (3) Establish suitable training programs for older age groups in the Army and (4) Document incidence of sports/training injuries and seek their prevention.

25. (U) 78 10 - 79 09 (1) In a longitudinal study of comparative responses of male and female cadets to the physical training program at the U.S. Military Academy, no changes in the pattern of aerobic fitness could be found during the second academic year, i.e., the gap in aerobic power between genders did not undergo further narrowing. (2) Research has been initiated to find a means of measuring aerobic efficiency, as opposed to aerobic power, in the assessment of physical fitness. Modifications in the technique of anaerobic threshold looks encouraging for this purpose. (3) Data has been collected to compare the three modes of muscle strength testing: isometric, isokinetic and isotonic.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.27.77.A ENVIRONMENTAL STRESS PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 047 Improvement of Physical Fitness Training and Prevention of Injuries Related to Training

Study Title: Long Term Effects of Similar Training Environment on Men and Women

Investigators: William L. Daniels, Ph.D., CPT, MSC, James E. Wright, Ph.D., CPT, MSC, Dan S. Sharp, M.D., CPT, MC and Dennis M. Kowal, Ph.D., CPT, MSC

Background:

Recently, there has been considerable interest in the military concerning the physical fintess levels of females, their responses to physical training, and comparisons of males and females in terms of physical fitness. Much of this interest has been precipitated by the large increase in the number of women and their entrance into job specialties traditionally held by males. While there have been many reports of the effects of training on females (1-3) and even reports comparing males and females in the same training program (4,5), these studies involved training of relatively short duration (6-8 weeks). It is not known how extended military training will affect the differences in the levels of fitness which have been reported for males and females. The purpose of this study was to compare the responses of males and females to similar training when the regimented lifestyle imposed comparable environmental and dietary factors. This opportunity became available as a result of our collaboration with the Department of Physical Education at the U.S. Military Academy.

Progress:

Subjects for this study were volunteers from the group of 30 male and 30 female cadets who participated in an evaluation of the initial six weeks training program given to all cadets (5). Those subjects who volunteered to continue in

this study were evaluated on five separate dates (Table 1). These dates were selected so that they coincided with the beginning and the end of the training programs of which all cadets undergo during their first two summers. The final test date was at the end of their second academic year.

The training program during the first summer was 6 weeks in duration and similar to a basic training program. Physical training consisted of calisthentics, grass drills and a 30 minute run 5-6 times per week. The effects of this portion of training have been described elsewhere (5). The second summer's training program is designed to give cadets seven weeks of military field training. It includes infantry patrolling, hand to hand combat, wilderness survival, as well as daily calisthentics and running. During the academic year, all cadets are required to participate in either an intramural, club or varsity sport and to attend physical education classes three times per week. Although the training was not identical during the entire study period, it was similar. All cadets lead a very active life style and are required to participate in demanding physical activities regularly (e.g. physical training tests). The regimented life which is in effect constantly assures similar dietary, sleeping and recreational habits. Cadets are also given annual medical and dental examinations to insure excellent health.

Subjects underwent height, weight and skinfold assessments. Skinfolds were used to estimate body fat using the formula of Durnin and Wormesley (6). All skinfold and weight measures were performed by the same individual in order to make comparisons as reliable as possible.

TABLE 1

Schedule for Testing

1. JUNE 1977 - Aerobic Power
   1st Summer of Training
2. AUGUST 1977 - Aerobic Power
   1st Academic Year
3. JUNE 1978 - Aerobic Power and Muscle Strength
   2d Summer of Training
4. AUGUST 1978 - Aerobic Power and Muscle Strength
   2d Academic Year
5. MAY 1979 - Aerobic Power and Muscle Strength

During the last three test dates, subjects performed maximal isometric voluntary contractions. Three muscle groups were tested: upper torso (arm and shoulder) flexors, knee extensors and back extensors. Strength of the upper torso was assessed with the subject securely fastened with a lap belt in a sitting position. The upper arms were parallel to the floor and the arms formed a 90^o angle when an overhead bar was grasped. This bar was secured with a stationary cable and the force exerted was measured with a cable tensiometer (Pacific Scientific Corp.).

Strength of the leg extensors was determined by testing the quadriceps femoris muscle. The subject sat securely fastened in a chair with knees bent at 90^o and grasped handles on the seat edge for additional stability. He or she exerted outward force on a bar placed against the arch of his feet and connected to a cable tensiometer transducer. The apparatus which was used to make the muscle strength measurements was developed by this Institute and is described in detail elsewhere (7).

During the testing, subjects also performed a running maximal oxygen uptake ($\dot{V}O_2max$) determination. The test used was a modification of the test used by Mitchell et al (8). The number of cadets who were tested on each date decreased because of departure from the academy, injuries and unwillingness or inability to continue in the study.

Results are presented in two forms: presentation of all subjects tested and presentation of only those who participated on all five test dates. Appropriate statistical tests were performed on the data.

Table 2 lists the physiological data that was collected on all test subjects at the time of $\dot{V}O_2max$ determination. Despite the gradually decreasing "n", the results with the males are fairly consistent. They show very little change in $\dot{V}O_2$, HR_{max} and % body fat despite increased body weight. The results with females are not quite as consistent and a closer examination of those females who completed all testing is required. The physiological data collected on those subjects who completed testing on all five dates are listed in Table 3. The results from the muscle strength testing is illustrated in Table 4.

The results of this study confirm that both the male and female cadets are well-conditioned individuals when compared to a similar age group (2,3,4). However, the results also suggest that even with extended military training the average values for females do not approach those of males in terms of aerobic

power and muscle strength. This fact must be kept in mind when setting performance criteria in which males and females will be compared.

TABLE 2A

Physiological Data Collected at $\dot{V}O_2max$ on Male Subjects

MALES	JUNE 1977	AUGUST 1977	JUNE 1978	AUGUST 1978	MAY 1979
N	30	29	18	16	13
$\dot{V}O_2$MAX (ML/KG.MIN)	59.3 ±5.8	60.6 ±4.7	60.9 ±3.7	60.4 ±3.2	60.0 ±2.6
$\dot{V}O_2$MAX (L/MIN)	4.13 ±.54	4.27 ±.40	4.48 ±.34	4.51 ±.41	4.49 ±.40
HR_{MAX} (BTS/MIN)	193 ± 3	185 ± 5	189 ± 8	188 ± 7	189 ± 7
$\dot{V}_E$BTPS (L/MIN)	148.8 ±20.6	157.6 ±17.7	149.0 ±20.3	161.7 ±16.6	155.1 ±20.6
WT (KG)	70.6 ±7.6	70.5 ±6.6	73.9 ±7.7	74.6 ±6.7	75.1 ±8.0
% BODY FAT	13.1 ±3.2	11.1 ±2.8	13.8 ±2.5	12.6 ±2.5	12.2 ±3.0

TABLE 2B

Physiological Data Collected at $\dot{V}O_2max$ on Female Subjects

FEMALES	JUNE 1977	AUGUST 1977	JUNE 1978	AUGUST 1978	MAY 1979
N	30	26	16	13	9
$\dot{V}O_2$MAX (ML/KG.MIN)	45.9 ±5.1	49.7 ±4.2	48.8 ±4.7	49.2 ±4.1	45.6 ±2.8
$\dot{V}O_2$MAX (L/MIN)	2.66 ±.34	2.86 ±.29	2.92 ±.29	2.98 ±.23	2.75 ±.21
HR_{MAX} (BTS/MIN)	186 ±18	183 ± 7	191 ± 5	185 ± 6	188 ± 7
$\dot{V}_E$BTPS (L/MIN)	99.2 ±15.3	111.0 ±12.1	99.6 ±15.5	108.7 ±14.5	102.4 ±9.9
WT (KG)	58.1 ±6.1	57.7 ±5.0	59.9 ±4.5	61.6 ±4.2	60.5 ±5.2
% BODY FAT	24.2 ±4.1	20.8 ±3.5	22.5 ±3.0	23.1 ±3.2	23.6 ±5.8

TABLE 3A

Physiological Data Collected on $\dot{V}O_2max$ on Male Subjects Tested on All Dates

MALES	JUNE 1977	AUGUST 1977	JUNE 1978	AUGUST 1978	MAY 1978	TUKEY'S HSD
N = 12						
$\dot{V}O_2MAX$ (ML/KG.MIN)	58.5 ±3.5	60.1 ±3.9	60.8 ±4.2	59.9 ±3.4	60.3 ±2.8	N.S.
$\dot{V}O_2MAX$ (L/MIN)	4.13 ±.46	4.21 ±.31	4.41 ±.34	4.43 ±.45	4.54 ±.41	.21
HR_{MAX} (BTS/MIN)	190 ± 6	185 ± 6	190 ± 7	189 ± 6	188 ± 7	N.S.
$\dot{V}_EBTPS$ (L/MIN)	140.1 ±19.3	150.5 ±29.3	141.4 ±19.3	157.6 ±16.9	156.6 ±22.2	13.3
WT (KG)	70.5 ±8.1	69.9 ±7.7	72.2 ±8.0	74.1 ±8.0	75.0 ±8.4	1.6
% BODY FAT	12.1 ±2.3	9.7 ±3.0	12.1 ±2.2	12.1 ±2.3	12.1 ±2.8	1.3

TABLE 3B

Physiological Data Collected on $\dot{V}O_2max$ on Female Subjects Tested on All Dates

FEMALES	JUNE 1977	AUGUST 1977	JUNE 1978	AUGUST 1978	MAY 1978	TUKEY'S HSD
N = 7						
$\dot{V}O_2MAX$ (ML/KG.MIN)	44.2 ±4.8	48.8 ±3.7	48.1 ±4.4	49.0 ±4.4	45.9 ±2.8	3.11
$\dot{V}O_2MAX$ (L/MIN)	2.47 ±.26	2.74 ±.24	2.78 ±.29	2.91 ±.28	2.67 ±.14	.26
HR_{MAX} (BTS/MIN)	193 ± 7	186 ± 9	193 ± 6	186 ± 7	192 ± 5	7
$\dot{V}_EBTPS$ (L/MIN)	90.8 ±17.4	105.1 ±14.5	93.6 ±17.6	107.4 ±19.1	100.7 ±10.8	16.6
WT (KG)	56.1 ±3.9	56.2 ±3.0	57.9 ±4.0	59.4 ±3.2	58.3 ±3.2	2.0
% BODY FAT	22.4 ±3.3	19.3 ±2.4	21.3 ±2.6	21.9 ±2.8	21.0 ±3.1	1.8

TABLE 4

Maximal Isometric Muscle Strength of Male and Female Cadets

	June 1978	August 1978	May 1979
Upright Pull			
Males	134.3 ± 6.4	140.9 ± 5.9	143.3 ± 6.3
Females	88.1 ±3.9	87.8 ±4.1	92.0 ±6.8
Upper Torso			
Males	106.6 ± 4.7	113.9 ± 3.7	115.8 ± 5.4
Females	66.8 ±1.9	70.5 ±1.9	69.3 ±1.5
Trunk Extensors			
Males	87.1 ±3.5	79.7 ±3.1	86.2 ±3.8
Females	59.2 ±2.8	55.0 ±2.5	58.1 ±3.4
Leg Extensors			
Males	181.0 ±9.7	193.6 ±8.4	No Data
Females	124.2 ±6.7	134.5 ±9.4	No Data

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 047 Improvement of Physical Fitness Training and Prevention of Injuries Related to Training

Study Title: Determination of Anaerobic Threshold During Maximal Exercise Testing

Investigators: William L. Daniels, CPT, MSC, Ph.D., Dan S. Sharp, CPT, MC, M.D. and Dennis M. Kowal, CPT, MSC, Ph.D.

Background:

Traditionally, an individual's level of cardiorespiratory fitness has been determined by measuring maximal oxygen consumption ($\dot{V}O_2max$) (1,2). However, $\dot{V}O_2max$ is not the only factor which determines performance (3). Recently, determination of the lactate breaking point (LBP) or anaerobic threshold (AT) has been suggested as a parameter which may give important information on fitness (4,5). It has also been reported that the LBP can be measured by changes in certain respiratory parameters ($\dot{V}_E$, $\dot{V}CO_2$, $\dot{V}_E/\dot{V}_{O_2}$) (5,6). The purpose of this protocol was designed to evaluate walking tests which used incremental work levels at various time intervals in order to compare different procedures for determining the LBP during which subjects achieved steady state.

Progress:

Ten male soldiers volunteered to participate in this study. Four were runners (Rs) who trained regularly. Three of these runners completed a marathon within a three month period prior to the start of the study with times of 2 hrs, 44 minutes, 3 hrs even, and 3 hrs, 34 minutes. The other six non-runners (NRs) were young soldiers who were physically active in recreational sports (e.g., basketball, softball, weightlifting) but did not participate in any regular training program. Before participation, informed consent was obtained and subjects were

familiarized with the test procedures. Subjects underwent a series of tests which included the following:

(1) Anthropometric measures.

(2) Running maximal oxygen uptake ($\dot{V}O_2$max R).

(3) One-minute incremental walking test.

(4) Three-minute incremental walking test.

(5) Five-minute walking test, and

(6) Thirty-minute walk at a single sub-maximal workload.

Anthropometric measurements included height, weight and skinfold thickness determinations. Skinfold thickness was measured with a Harpendin caliper at four sites; biceps, triceps, suprailliac and subscapular.

A running maximal oxygen uptake test was the initial procedure performed by each subject. This was a modification of the interrupted treadmill test described by Mitchell et al (7). An initial run for 6 minutes at 6 mph 0% grade was followed by a 5-10 minute rest period. Two to four additional runs of 3-4 minutes were performed, each followed by a rest period. Workloads were increased by adjusting speed and/or grade. During the last minute at each workload, expired air was collected in Douglas bags. Subjects breathed through a mouthpiece attached to a Kogel y-valve. A plateau in oxygen consumption ($\dot{V}O_2$) (increase $<$ 2 ml/kg.min per 2.5% grade increase) was defined as $\dot{V}O_2$max. Expired air was analyzed with a Beckman LB-2 CO_2 analyzer and an Applied Electrochemistry, Inc. S3-A O_2 analyzer.

Following the max run, subjects performed a series of treadmill walking protocols. The first session consisted of walking at 3 mph with a 3% grade increase each minute until the subject could no longer continue. During the last 30 seconds at each workload, expired air was collected and analyzed as described above. In addition, a one ml sample of venous blood was withdrawn for lactate determination. Blood was withdrawn through 19 gauge perdiatric needle, an intravenous injection set, which was inserted into a vein on the back of the hand or in the forearm. The needle and tubing (total volume 0.5 ml) was kept patent with a heparin lock. Drawn blood samples were immediately placed in 8% perchloric acid and later analyzed spectrophotometrically.

The next procedure consisted of walking as described above except that the workload was increased every three minutes until the subject could no longer

continue. $\dot{V}O_2$ was measured as above, and blood lactate was measured after 1 minute and 3 minutes at each workload. Maximal oxygen consumption for walking ($\dot{V}O_2$max W) was determined from the results of these two tests.

For the next session subjects walked for five minutes at five workloads. Workloads were selected for each subject so that two were below the point where venous lactate began to accumulate exponentially, one was at or near that point and two were above it. $\dot{V}O_2$ was measured at the end of each workload and lactate after 1, 3 and 5 minutes at each workload.

In the final procedure, subjects walked for 30 minutes at a single workload. Based upon the results of the previous walks, a workload was selected for each subject which was just above the lowest workload at which venous lactate began to increase exponentially in any of the three previous tests. All subjects walked for three minutes at 3 mph 0% grade and then went immediately to the appropriate grade and walked for 30 minutes. Samples for lactate determination were withdrawn at 1, 3, 5, 8, 10, 13, 15, 18, 20, 23, 25, 28 and 30 minutes. $\dot{V}O_2$ was measured every five minutes.

All walking tests were performed at 3 mph and at least one day of rest separated procedures. No more than two procedures were performed in any one week. Statistical comparisons were made using an analysis for variance for repeated measures or an unpaired t-test. Tukey's Test was used for post-hoc comparisons. For statistical significance, we used $p \leq 0.05$.

The anthropometric data is summarized in Table 1. The maximal physiological data that was collected while walking ($\dot{V}O_2$max W) and running ($\dot{V}O_2$max R) are listed in Table 2. Runners were taller, heavier and older than non-runners. The $\dot{V}O_2$max R of runners was 28% higher ($p < 0.005$) than non-runners. $\dot{V}O_2$max W was 10.8% and 19.7% lower in NRs and Rs, respectively.

TABLE 1

Descriptive Data on Subjects

	Ht(cm)	Wt(kg)	Age(yrs)	Running $\dot{V}O_2$max (ml/kg.min)
Non-Runners				
S.M.	160.8	67.1	20	57.1
J.R.	173.9	56.4	24	53.5
C.H.	168.5	57.1	27	53.3
G.H.	178.4	74.1	21	51.0
W.G.	169.2	62.1	23	47.4
D.H.	171.1	65.8	21	53.3
$\bar{x}$	170.3	63.8	22.6	52.6
S.D.	± 5.9	±6.7	±2.5	±3.2
Runners				
B.K.	177.8	70.7	31	64.5
J.K.	181.0	68.7	30	67.9
B.M.	169.3	74.4	25	61.4
B.D.	177.0	79.1	31	65.6
$\bar{x}$	176.3	73.2	29.3	64.8
S.D.	± 5.0	±4.6	±2.9	±2.7

TABLE 2

	VO_2 (L/MIN)	VO_2 (ML/KG.MIN)	V_{CO_2} (L/MIN)	VEO	HEART RATE (BEATS/MIN)	V_EBTPS (L/MIN)	R
NON-RUNNERS							
RUNNING							
$\bar{x}$	3.34	52.6	61.9	35.7	195	117.4	1.12
S.D.	±0.39	+3.2	+6.5	+6.2	±12	±14.6	±.06
WALKING							
$\bar{x}$	3.00	46.9	53.2	35.0	188	106.1	1.13
S.D.	±0.36	+3.5	+5.4	±7.1	±9.7	31.2	±.04
RUNNERS							
RUNNING							
$\bar{x}$	4.65	64.9	72.2	35.6	183	166.2	1.12
S.D.	±0.23	+2.7	+3.5	±1.8	±2	±14.9	±.04
WALKING							
x	3.77	52.0	54.6	33.3	176	126.8	1.04
S.D.	±.75	±5.4	±8.6	±3.8	±10	±24.6	±.08

Venous lactate curves were plotted on all subjects while walking with grade changes at 1, 3 and 5 minute intervals. For all procedures runners had less lactate accumulation for each absolute workload.

Based on the results of these previous walks, a single workload was selected for each individual which was just above the level at which lactate began to accumulate. The average workload was 14% (range 12-15%) grade and 23.8% (range 18-27%) grade for NRs and Rs, respectively. Table 3 lists the lactate values for Rs and NRs during the 30 minute walk. The increase in venous lactate was almost identical for the first five minutes in both groups. However, by ten minutes lactate levels in NRs had risen to 2.7 mM/L while it decreased in Rs to 1.9 mM/L. Rs continued to show a decreasing trend in lactate, reaching a minimum after 25 minutes.

TABLE 3

Lactate (mM/L0 During Exercise Time (Minutes)

		0	1	3	5	10	15	20	25	30
NRs	$\bar{x}$	1.4	1.3	1.7	2.1	2.7	2.8	2.8	2.9	2.9
	S.D.	±.3	±.3	±.5	±.7	±.9	±1.1	±1.0	±1.1	±1.0
Rs	$\bar{x}$	1.3	1.4	1.7	2.4	1.9	1.9	1.8	1.7	1.8
	S.D.	±.8	±.9	±1.0	±1.1	±.9	±.9	±.8	±.7	±.9

The mean difference in the change in lactate between 5 to 10 minutes was significant ($p < 0.05$) when NR s were compared to R's. These results suggest that not only does training delay the onset of lactate accumulation during exercise, but it also accounts for the decrease in the initially elevated blood lactate that occurs during steady state exercise at their particular workloads. This suggests that the accumulation of lactate is reversible during steady state exercise in trained individuals. Whereas, in untrained individuals we see a plateauing in the lactate response to steady state exercise.

Further analysis of the data is continuing in order to determine whether or not certain ventilatory parameters are good predictors of the onset of lactate accumulation.

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(83048)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OA 6123	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
78 10 01	D. Change	U	U	NA	NL	[X] YES [ ] NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	048
b. CONTRIBUTING				
c. ~~XXXXXX~~	CARDS 114f			

11. TITLE (Precede with Security Classification Code)* (U)Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

013300 Protective Equipment; 022400 Bioengineering

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
64 01	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	8	293
	CURRENT 80	10	425

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

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20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

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PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

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SOCIAL SECURITY ACCOUNT NUMBER

ASSOCIATE INVESTIGATORS

NAME: GOLDMAN, Ralph F., Ph.D.

NAME: DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Tolerance Prediction; (U)Protection; (U)Biophysics; (U)Thermal Exchange; (U)Insulation (clo); (U)Evaporative Cooling Index; (U)Moisture Permeability Index

23. TECHNICAL OBJECTIVE.* 24. APPROACH. 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Study energy exchanges in Man-Clothing-Environment system, to provide basis for improving thermal protection and recommending crew environments in military vehicles.

24. (U) Analyses of materials, uniforms and/or equipment using heated "sweating' flat plates, manikins, etc. indicate their effects on heat and moisture exchange and aid in predicting the user's physiological responses. Results provide guidance for military designers and identify stressful items or environments. Findings may be verified on soldiers in chamber or field studies.

25. (U) 78 10 - 79 09 Studies of auxiliary cooling for individual soldiers using liquid air, and ice systems were intensified to resolve heat stress problems in operations in hot environments. Various foam-type sleeping bag pads showed superiority over the insulated air mattress both in protection and weight, with only a small increase in volume. Studies on vacuum packed survival bags for aircraft showed no adverse effects of vacuum packaging, altitude, cold exposure, or vibration. Insulation and permeability of Combat Vehicle Crewmen clothing, Republic of Korea uniforms, and cold weather footwear items including Marine Corps footwear systems were measured. Techniques to localize heat leakage in clothing using an infrared scanning camera were perfected. Studies of thermal response characteristics and programming for temperature control of a new, multisection copper foot for footwear evaluations were initiated. An improved form of WBGT heat stress index was evaluated in-house and is being evaluated by field MEDACS.

*Available to contractors upon originator's approval

DD FORM 1 MAR 68 1498 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.27.77A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments

Study Title: Evaluation of Two Experimental Ballistic Undergarments

Investigators: Clement A. Levell and John R. Breckenridge

Background:

A Kevlar undershirt-type vest like that originally developed for law enforcement personnel is currently being considered to meet the specified ballistic protection requirements for a new Combat Vehicle Crewman's (CVC) uniform. Police experience with this type vest has indicated low acceptance in hot-humid environments owing to the increased discomfort and elevated heat stress caused by the inability of the wearer to freely evaporate secreted sweat. The 8 to 16 plies of Kevlar in the vest offer moderately high resistance to vapor diffusion, causing a buildup of liquid on the skin. This liquid tends to be blotted up by the Kevlar unless waterproof coverings or water-repellent treatments are employed, and the ballistic protection is gradually degraded as liquid accumulates within the plies. Manufacturers have proposed two solutions which might help to keep the Kevlar dry without employing vapor barriers or water-repellent treatments, both of which increase resistance to vapor transport and reduce evaporative cooling; these solutions, if successful, could significantly lower environmental stress and improve comfort. One, Safariland's "Cool Shirt" employs a spacer material to hold the vest away from the skin. It is argued that such a spacer would also promote ventilation across the skin and increase evaporative cooling during exercise. This contention is, however, not supported by the findings of an earlier study in which spacer underwear was used.(1) The second solution employs a layer of Gore-tex between the skin and the vest to prevent direct water uptake by the Kevlar. This relatively new fabric composite (Gore-tex) is a "one way" material, i.e., it blocks transfer of liquid water but permits relatively free passage of water vapor. Evaporative cooling can thus be maintained at a high level and alleviate the high heat stress associated with

impermeable or low permeability vapor barriers next to the skin. USANARADCOM has requested copper manikin assessments of the merits of these two approaches, to include measurement of the evaporative coefficients (i_m/clo) for police and CVC uniforms equipped with Kevlar ballistic vests, and data on the water pickup in the armor after 6-8 hours of wear on the "sweating" manikin in a hot humid environment.

Progress:

Copper manikin measurements at an air movement of 0.3 m/s indicate that the wearing of the Safariland "Cool Shirt" under the summer CVC uniform plus 16 ply Kevlar vest increases the system insulation value by 6% from 1.87 to 1.98 clo but that the shirt has no effect on permeability index i_m (constant at 0.37). However, these results mean that the evaporative heat transfer coefficient, i_m/clo, is decreased by 6% by wearing the "Cool Shirt"; in other words, heat stress and thermal discomfort would be higher when wearing the "Cool Shirt" with the CVC uniform.

The PACA manufactured Gore-tex shirt has not yet been delivered by USANARADCOM. Studies of water uptake by the Kevlar vest with the "Cool Shirt" are being delayed until receipt of the PACA item to permit both to be evaluated during the same time period, to insure that techniques for measuring water uptake, etc. are the same for both shirts.

LITERATURE CITED

Winsmann, F. R., R. G. Soule and R. F. Goldman. Underclothing and its physiological effects in a hot-dry environment. Clothing Res. J. 5:28-34, 1977.

Program Element:	6.27.77A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness, and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Insulation Characteristics of Canadian Aircrew Mukluk
Investigator:	John R. Breckenridge

Background:

U.S. Army Alaska, through USANARADCOM, has requested a comparison of the insulating characteristics of the Canadian Aircrew Mukluk with those of the currently authorized white insulated vapor barrier boot issued to U.S. troops and aircrews operating in extreme cold environments. Consideration is being given to the possibility of substituting the Canadian item for the white vapor barrier boot since the latter is in short supply, cannot readily be procured from American manufacturers, and is a more bulky, heavier item which has lower troop acceptance than the Canadian mukluk.

Progress:

Sectional insulation values for the Canadian Aircrew Mukluk and the standard white vapor barrier boot were measured using the Institute's 12-section electrically heated copper foot. The results are given in Table 1.

TABLE 1

Sectional Insulating Values (clo units)

Section No.	Location	Canadian Aircrew Mukluk	U.S. Cold-Dry V. B. Boot (March 1975 model)
4	Achilles	2.35	1.84
5	Heel	2.28	1.89
6	Ankles	2.69	1.84
7	Instep	1.88	1.23
8	Sidewall (Outer)	1.95	1.94
9	Sidewall (Inner)	2.47	2.45
10	Toecap	1.51	1.70
11	Foresole	2.82	2.61
12	Midsole	3.55	3.18
Overall		2.23	1.86

Findings of the study have been reported to USANARADCOM. The report noted that, although most sectional values were higher for the Canadian Mukluk, it might not in practice provide the greater protection which the comparison would indicate. Firstly, the toecap (section 10) of the mukluk provides less insulation (due to a thinner, less bulky configuration) than the vapor barrier boot and might be expected to compromise protection of the critical toe areas of the foot. Offsetting this reduced insulation over the toes was a higher insulating value under the toes (section 11) and vastly superior insulation over the instep (section 7). The 0.6 clo higher insulation over this section might effectively help in maintaining a higher blood temperature to the toes and/or higher blood flow, and thus counter-balance the tendency of the mukluk to allow higher heat loss from the toes. Our report also warned that the mukluk and vapor barrier boot should not be compared on the basis of overall insulation alone since evaporation of sweat from the foot would not be blocked in the mukluk; evaporative heat loss from a wet sock could easily lower the effective insulating value of the mukluk to a lower value than for the vapor barrier boot, in which moisture within the boot has little (< 15%) effect on overall heat loss. It was also pointed out that the danger of wetting the inner layers of the mukluk would contraindicate its use where continuous temperatures below -20°C could not be guaranteed.

LITERATURE CITED

Breckenridge, J. R. Effect of wet insulation in vapor-barrier cold weather boots. Text. Res. J. 37:809-811, 1967.

Program Element:	6.27.77A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Insulating and Performance Characteristics of Ensolite Foam Sleeping Bag Pads
Investigators:	John R. Breckenridge and Thomas L. Endrusick

Background:

Inflatable air mattresses have been used under sleeping bags for many years to reduce heat losses between the sleeping soldier and the ground. These heat losses are excessive without some form of supplementary insulation beneath the bag since the bag insulation beneath the soldier is severely compressed by his weight. Recent U.S. Army air mattresses have contained insulating batting to reduce air currents in the channels and greatly improve the protection provided by the mattress. However, recognition of several deficiencies of air mattresses, namely, excessive weight, bulkiness, and tendency to leak, has aroused interest in the merits of various types of foam pads for under-bag protection in both the civilian and military communities. These pads are lighter in weight, can provide equivalent improvement in protection and reportedly can be easily rolled into small volumes for back-packing.

The present study was initiated as a collaborative effort of USARIEM and Clothing, Equipment and Materials Engineering Laboratory (CEMEL), USANARADCOM to assess the merits of foam pads by evaluating several commercial types, available materials, and foreign items for insulating characteristics, stability and ease of rolling in the cold, and weight and bulk volume. A standard insulated U.S. Army inflatable mattress was used as control for comparisons.

Progress:

Eight foam pads were evaluated for their insulative characteristics, weight, and rolled volume. Each pad was placed in turn under a standard extreme cold LINCLOE sleeping bag, and the total insulation of the system measured using a copper manikin in the bag. A U.S. standard insulated inflatable pad was also used in the same manner for comparison purposes. The pads were also weighed, and bulk volume after rolling tightly determined with a tape measure. Results obtained are given in Table 1. Comparison of the results with the foam pads show that they weighed considerably less than the U.S. mattress in all cases except Sample #9, a 5/8" Ensolite pad which was marginally heavier. However, this pad provided an overall insulation for the bag-pad system which was 1.01 clo higher than with the inflatable mattress; all other pads also provided higher protection of 0.3 clo or more. All of the pads were rolled without damaging them at -30°C, except for pad No. 5, which was easily broken along the edges while it was being rolled.

TABLE 1

Physical Data on Foam Sleeping Pads:

Combined Insulation Values with Extreme Cold LINCLOE Bag

	Sleeping Pad	Weight lb.	Weight kg.	Rolled Volume(ft^3)	clo
1.	Thermopack, Closed Cell PVC 24"x64"x3/8"	0.85	0.39	1.64	8.88
2.	Thermopack, Closed Cell PVC 24"x64"x3/8"	1.38	0.63	1.49	8.46
3.	Trailpack, Closed Cell PVC 21"x56"x3/8"	1.15	0.52	1.40	8.74
4.	Ensolite Closed Cell Foam 21"x56"x3/8"	1.21	0.55	1.41	8.46
5.	Foamlite Mountain Mat Polyethylene Foam Closed Cell 24"x60"x3/8"	0.63	0.29	1.51	8.40
6.	U.S. Army Standard Insulated Inflated Pneumatic Mattress 25"x72"x4"(inflated)	3.50	1.59	N/A	8.06
7.	Ensolite, Uniroyal Type M 25"x72"x3/8"	1.93	0.87	2.02	8.67
8.	Ensolite, Uniroyal Type I 25"x72"x3/8"	2.03	0.92	1.70	8.88
9.	Ensolite, Uniroyal Type I 25"x72"x5/8"	3.67	1.66	2.20	9.07
10.	British Sleeping Pad 23"x75"x3/8"	1.25	0.57	1.60	9.17

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Flat Plate Evaluations on Five Fabrics Before and After Laundering
Investigators:	John R. Breckenridge and John Fiumara

Background:

The "sweating" guard ring flat plate is an electrically heated biophysical device which is used for the screening of textile fabrics for their heat and moisture transfer properties to provide a basis for selection of the most satisfactory fabrics for incorporation in military clothing and personal equipment items. Clothing, Equipment and Materials Engineering Laboratory (CEMEL), USANARADCOM has requested an evaluation of five fabrics before and after launderings in connection with their investigation of alternative fabrics for the current standard Army dress uniform. CEMEL has a flat plate facility for measuring thermal insulating characteristics of fabrics, but the facility lacks the capability of measuring the more important parameter related to a fabric's ability to transmit moisture vapor; this so-called moisture permeability index is directly related to the evaporative cooling characteristics, i.e., the ability to remove heat from the body by sweat evaporation. This Institute has one of the few such facilities in the United States, and is relied on by CEMEL for conduct of all fabric measurements where such evaporative transfer is a major consideration.

Progress:

This study was delayed for over three months by a major breakdown in the electrical circuits of the "sweating" plate caused by water leakage. Extensive rewiring and waterproofing of the plate was required to make the plate

operational once again. Measurements of the insulating value of the five fabrics before and after laundering have been completed, but assessment of their evaporative heat transfer characteristics has not yet commenced. These fabrics, were of polyester, or polyester/cotton and polyester/wood blend, with weight ranges from 6.4 to 8.0 oz/yd^2. They were all of similar thickness and thus the insulating values varied only slightly, from 0.52 clo to 0.57 clo for the unlaundered samples, and from 0.55 clo to 0.63 clo after laundering. These values include 0.43 clo of insulation which is attributable to the air layer on the outer surface of each fabric. The insulation increase of about 0.05 clo, average, after laundering is due to increased thickness resulting from a raised nap on each fabric as a result of the laundering process.

Measurements of the evaporative transfer characteristics of these fabrics will be commenced shortly.

Program Element:	6.27.77A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness, and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Insulating Value of 14 Footwear Systems
Investigator:	John R. Breckenridge

Background:

Footwear developers from Clothing, Equipment and Materials Engineering Laboratory (CEMEL), USANARADCOM regularly request Institute assistance in evaluating insulating characteristics of commercial and prototype footwear. Sectional insulating values measured on a 12-section electrically heated copper foot device provide CEMEL guidance in selecting best footwear designs or modifying prototypes to provide optimal foot protection. The present work request is a blanket order covering a total of 14 evaluations of footwear items as they are required by CEMEL throughout the year.

Progress:

During the year, nine of the fourteen footwear systems covered under this study were evaluated for CEMEL. Four of the systems consisted of an Alaskan Pac Boot (shoepac style of boot) with different constructions of insulating liners. The other five systems were Combat Vehicle Crewmen boots with and without saran and poron foam insoles, measured alone and under a vinyl overboot. Results for the Alaskan Pac and CVC Boot systems are given in Table 1, and for the CVC systems in Table 2.

TABLE 1

Insulation (clo) Values of Alaskan Pac Boot with Four Different Insulating Inserts*

Section	Insert**			
	A	B	C	D
Achilles	2.03	2.28	2.85	2.80
Heel	1.92	1.90	2.14	2.10
Instep	2.04	1.98	1.78	1.79
Sidewall (outer)	1.87	2.11	2.25	2.20
Sidewall (inner)	2.20	2.44	2.79	2.63
Toecap	1.27	1.53	1.53	1.47
Foresole	1.61	1.59	1.59	1.60
Midsole	2.29	2.29	2.59	2.54
Overall	1.91	2.03	2.15	2.12

*Note: all systems included one sock, wool, cushion sole worn next to the copper foot.

**Inserts were built up of the following components:

A - standard coarse wool fabric (standard insert)

B - 1/8" Volara, plus wool

C - wool, plus 400 g/m^2 Thinsulate, plus 1/8" foam, plus nylon tricot facings

D - Volara, plus polyethylene foam, plus 1/4" wool, plus nylon tricot facings

The results of these measurements show in general that the multi-layered liners were more effective insulators than wool alone. Decreases in instep protection with C and D were due to failure of the inserts to completely cover the instep. The foresole insulation was apparently unaffected by the insert composition (although midsole insulation was increased with C and D) suggesting that the foresole thickness was constrained by the inside of the Pac Boot and the copper foot shell. No important advantages can be observed for the insert employing Thinsulate (reportedly a "miracle" insulating material) when compared to D, a similar insert employing foam. This failure to show superiority of Thinsulate has been found in several other insulation measurements on cold weather clothing systems and extremity items.

TABLE 2

Insulation (clo) Values for Combat Vehicle Crewmen Boots with Various Insole-Vinyl Overboot Combinations*

Section	Boot Only	With Saran Insole	With Poron Insole	With Saran Insole and Overboot	With Poron Insole and Overboot
Achilles	1.72	1.61	1.58	1.64	1.63
Heel	1.30	1.31	1.25	1.34	1.34
Instep	1.59	1.52	1.54	1.86	1.80
Sidewall (outer)	1.29	1.24	1.24	1.49	1.47
Sidewall (inner)	1.64	1.64	1.62	1.89	1.88
Toecap	1.01	0.97	0.93	1.11	1.12
Foresole	0.85	1.01	0.99	1.22	1.29
Midsole	1.14	1.35	1.40	1.72	1.78
Overall	1.34	1.38	1.35	1.57	1.57

*Note: all systems included one sock, wool, cushion sole worn next to the copper foot.

The results in Table 2 show that, essentially, an insole raised the insulation of the sole areas of the systems but caused insulating values of areas above the foot (instep and toecap) to be reduced slightly. The latter was caused by positioning of the foot higher in the boot with an insole in place, thereby reducing thicknesses of the air space (or sock) between the copper foot and the boot instep and toecap, respectively. As expected, the vinyl overboot increased the protective characteristics of the CVC boot over all sections. The improvements noted for the instep (0.3 clo), toecap (0.2 clo), and foresole (0.2 clo) are potentially important since they increase the likelihood that the critical toe areas of the foot will be better protected, both because of improved insulation around the toes and over those areas through which the blood supply to the toes pass (e.g., instep).

Results of measurements on the Alaskan Pac CVC Boot systems have been forwarded to CEMEL, USANARADCOM by Disposition Form.

Program Element:	6.27.77A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness, and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Insulating Value of Vacuum-Packed Survival Type Sleeping Bags
Investigators:	Thomas L. Endrusick and John R. Breckenridge

Background:

Early in 1978, Clothing, Equipment and Materials Engineering Laboratory (CEMEL) of USANARADCOM was tasked with the development and/or procurement of a sleeping bag for a Cold Weather Aircraft Survival Kit which would provide enough insulation to permit at least four hours of uninterrupted sleep under Arctic temperatures down to -40°C. Measurements made on a candidate commercial bag, a North Face Expedition Bag, indicated almost the same insulating value on bare ground as the U.S. standard LINCLOE extreme cold bag (8.12 versus 8.3 clo); the North Face bag had 1.82 kg (4 pounds) of down filling but weighed only 2.5 kg (5.5 pounds) complete, compared with a weight of 4.3 kg (9.5 pounds) for the LINCLOE bag. This North Face bag appeared to have sufficient insulating value, according to heat transfer equations, to meet the four hour sleep requirement at -35°C and probably at -40°C. CEMEL accordingly made the decision to have several of the North Face bags vacuum-packaged to permit further study of the insulating characteristics of this bag after undergoing simulated in-flight conditions, e.g., cold exposures at altitude, vibration, and long-term vacuum packaging as in a survival kit stored in the aircraft. USARIEM was asked to conduct two separate series of measurements with the copper manikin, namely (1) assessment of the bag's insulating characteristics immediately after removal from its packaging and after up to four day's usage with the manikin, and (2) study of possible deleterious effects from cold exposure, altitude, and vibration.

Progress:

Phase I: A total of five vacuum-packed North Face Expedition Bags was measured with the copper manikin; bags were removed from their packaging as they were required, and "fluffed" by shaking for 2-3 minutes before placing the manikin inside. After the measurements on the first day, the manikin was left in the bag without further "fluffing" until study of the bag was complete, except for one sample which was "refluffed" each morning. A summary of insulating values for the five bags by day is given in Table 1.

TABLE 1

Insulating Values (clo units) of Vacuum Packed North Face Expedition Bags; Changes with Time Out of Packaging (Measured without Underpad or Mattress)

Sleeping Bag	Day 1	Day 2	Day 3	Day 4
Sample #3	7.88	8.29	8.27	---
Sample #8	7.49	7.52	7.80	8.17
Sample #13	7.44	7.56	7.60	---
Sample #23	7.59	7.59	---	---
Note: Above samples were not refluffed between daily measurements.				
Sample #18	7.39	7.60	7.93	8.15
Note: Sample refluffed between daily measurements.				
Control Bag (stored rolled since 1974)	8.12	---	---	---
Standard LINCLOE Extreme Cold Bag w/o underpad	8.32	---	---	---

The results show that all bags had less insulation on the first day after removal from their packages than a control bag which had been stored loosely rolled since 1974 (7.4 to 7.9 clo vacuum packed versus 8.12 clo for the rolled bag). However,

3 of the 4 vacuum packed bags increased in insulating value on subsequent days without "refluffing." Two of these bags reached the value for the control bag, after 3 and 4 days, respectively. The sample which was "refluffed" daily showed a steady increase in insulating value with time, but barely more rapidly than sample #8, which was measured without daily "fluffing."

Phase II: One each of the North Face Expedition Bags was measured after (1) vibration such as might be produced in an aircraft, (2) exposure to a -40°C environment, and (3) exposed to -25°C environment at a simulated 25,000 ft. altitude. Only the latter was vacuum-packaged at time of exposure. Results of these measurements are given in Table 2.

TABLE 2
Insulating Values (clo units) of North Face
Expedition Bags after Vibration,
Cold, and Cold/altitude Exposures

Sleeping Bag	clo value
Sample #23, after vibration exposure	7.85
Sample #6, after -40°C exposure	8.39
Sample #30, after -25°C, 25,000 ft. altitude exposure (vacuum packed)	7.70

After vibration, sample #23 measured 7.85 clo, versus 7.59 clo following removal from vacuum packing (see Table 1); apparently vibration increased the loft of the down filling slightly. Bag #6 had previously been removed from its packaging and loft-tested at -40°C. This bag had been out of its packaging for over a week prior to insulation measurement, thus accounting for the high value obtained. Bag #30, studied at -25°C and 25,000 ft. altitude for possible package leaks, was not removed from its packaging until immediately before manikin evaluation. Presumably the 7.70 clo value on the one day of measurement would have increased with time as did the bags in Phase I.

This study has been completed except for one insulation measurement at -40°C on a vacuum packed bag which has been cold soaked at -40°C. This measurement is necessary to determine that a cold bag will loft satisfactorily in a -40°C environment.

Program Element: 6.27.77A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments

Study Title: Auxiliary Cooling by Liquid and Air Ventilated Systems: Phase I (Copper Man Assessment)

Investigator: George F. Fonseca

Background:

Personnel operating in armored fighting vehicles in hot environments can be exposed to temperature and humidity combinations which can rise to thermally intolerable levels. Under these extreme environmental conditions, the operational performance of these combat personnel can be seriously impaired, even when they are operating at low activity levels. When the hatches of these vehicles are closed during periods of heavy engagement or during a chemical, bacteriological (CB) attack, the heat stress imposed on these combat crewman could minimize their effectiveness in battle. This could result in these crewman having a serious loss in operational efficiency or in their becoming heat casualties. It is becoming more evident that some form of auxiliary cooling for these combat vehicle crewmen is a basic requirement for their survival in hot environments.

An earlier study completed about two years ago (1) determined the cooling provided by four different water-cooled undergarments. This cooling in watts was directly measured on a sectional, copper manikin and represents the absorption of heat produced by the metabolic processes of the body plus that from the ambient environment in the vehicle. Although this study showed that these water-cooled undergarments did not by themselves completely isolate the manikin surface against heat gain from the hot environment, they did remove about one-half of the total potential for heat gain from the ambient environment before the heat reached the manikin surface. This study also showed that the cooling was almost directly proportional to the difference between the manikin

skin temperature and the inlet temperature of the cooling water flowing in the water-cooled undergarment.

Progress:

This present study continues the experimental effort of the earlier water-cooled undergarment study in support of a project to develop suitable auxiliary cooling systems for personnel operating in armored fighting vehicles in hot environments. Two types of cooling mode (liquid and air) are to be investigated. Studies are required on the extent of body coverage required to effect adequate metabolic heat dissipation (e.g. face ventilation, head/neck/torso or whole body cooling). This study consists of two phases. The first phase (copper manikin phase) will identify those systems considered as practical and adequate for cooling combat vehicle crewmen by first establishing liquid/air flow and temperature requirements for the various cooling configurations; water-cooled cap, water-cooled cap plus water-cooled vest, water-cooled vest, water-cooled undergarment, short and water-cooled undergarment, long. These water-cooled undergarments will be dressed on the sectional manikin with a Combat Vehicle Crewman (CVC) coveralls and the CVC coveralls plus a closed Chemical/Bacteriological (CB) ensemble. All ensembles will be exposed to two chamber environments: 29.4C, 85% relative humidity and a 51.7C, 25% relative humidity. In addition, two air-cooled undergarments will be studied. One garment will use forced ambient air (18 cfm) circulating over the manikin within the clothing layers and this same air-cooled undergarment will be used with forced air-conditioned circulating air.

The first part of the sectional manikin study determined the heat transfer properties of the CVC plus closed CB suit with and without each of the five water-cooled undergarments. These values of insulation (clo) and evaporative heat transfer (i_m/clo) are required to provide the baseline heat transfer values for these ensembles when exposed to the two hot chamber environments. These values are also used to calculate the correction values for the heat that is received or lost to the hot environment from the manikin surface. Net watts of cooling provided by a given water-cooled undergarment can thereby be determined. The basic, heat transfer values (clo and i_m/clo) for the CVC clothing plus CB Suit are given in Table 1.

TABLE 1

Heat Transfer Properties of Combat Vehicle Crewman Ensemble Plus Closed CB Suit

Manikin Sections	clo	im	im/clo
Head	2.54	.10	.04
Torso	3.38	.34	.10
Arms	2.68	.40	.15
Hands	1.29	.05	.04
Legs	3.11	.50	.16
Feet	1.65	.18	.11
Torso-Arms	3.10	.37	.12
Torso-Arms-Legs	3.10	.43	.14
TOTAL	2.63	.32	.12

Using these values, the heat exchange between the manikin surface and each of the two hot environments can be calculated. Figure 1 presents a bar graph showing the net heat exchange between the manikin surface and the two environments.

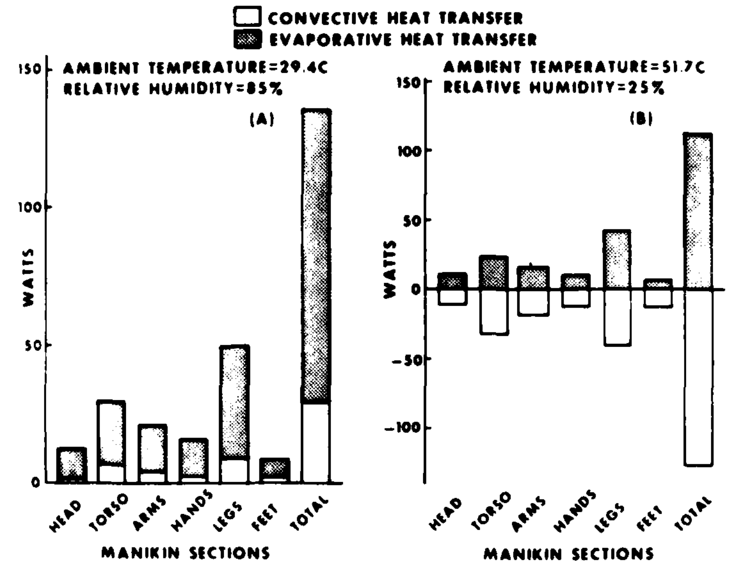

Figure 1. Convective and evaporative heat transfer (watts) over the six surface areas of the manikin for the CVC plus closed CB ensemble for two hot environments.

It can readily be seen from this figure that there not only is a net heat gain from the 51.7C, 25% relative humidity environment, but that all manikin sections show a net heat gain. That is, in this hot environment, all the metabolic heat produced by a body would go into body heat storage, resulting in a continual increase in body temperature with time so long as the body is exposed to this hot environment. This figure illustrates graphically the necessity of providing some type of auxiliary cooling to a body that is exposed to this, or similar, hot environments for an indefinite period of time if operational effectiveness of the vehicle crewman is to be preserved.

The net watts of cooling provided by four of the five water-cooled undergarments are given as a function of cooling water inlet temperature in Figure 2.

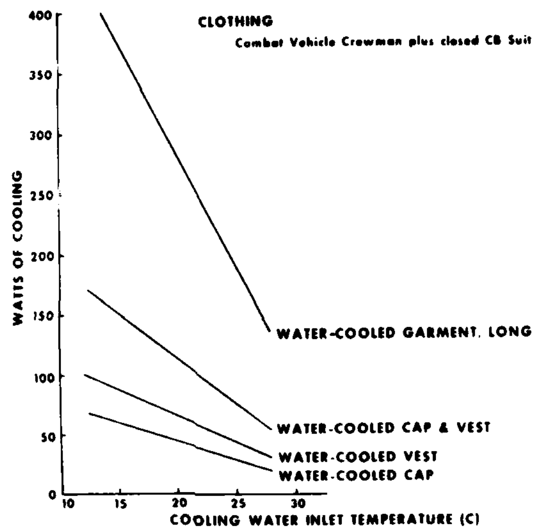

Figure 2. Watts of cooling provided by four water-cooled undergarments versus the cooling water inlet temperature.

Because of the combination of the closed CB suit and the two severe hot environments that were used in this study, the net heat removed by the cooling water flowing in the tubing of a given water-cooled undergarment is based on a wet (sweating) manikin skin (average manikin skin temperature of 35C). These curves are in agreement with the results of the previous water-cooled undergarment study--the net watts of cooling provided by these water-cooled undergarments is almost directly proportional to the difference between the manikin skin temperature and the cooling water inlet temperature of the water entering a water-cooled undergarment.

Table 2 gives the distribution of the total cooling provided by a water-cooled undergarment. In particular, for the water-cooled undergarment, long, which provides cooling over the head, torso, arms and legs of a body, these data show that only the torso receives a lower proportion of the total body cooling than its percentage contribution to the total surface area of the manikin. This result apparently occurs because of the water-cooled undergarment tubing distribution at the inlet manifold; the cooling water from the manifold flows over the arms prior to flowing over the torso.

TABLE 2

Distribution of the Total Cooling Provided by a Water-cooled Garment

WATER-COOLED GARMENT	PERCENT OF TOTAL WATTS OF COOLING MANIKIN SECTIONS					
	HEAD	TORSO	ARMS	LEGS	HANDS	FEET
Hood	100					
Vest		100				
Hood/vest	39	61				
Long	14	22	21	43		
% Manikin Surface Area	8	28	15	34	6	9

Figure 3 presents the net watts of cooling for the water-cooled undergarments, long, when worn with either the CVC clothing alone or the CVC clothing plus the CB closed suit for the two hot environments. This curve is based on all the data obtained under these conditions. Again, the net watts of cooling follows a straight line relationship with the cooling water inlet temperature.

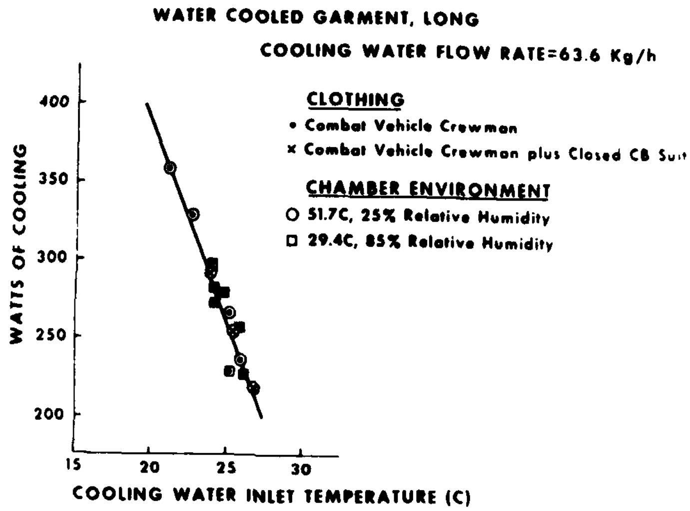

Figure 3. Watts of cooling versus cooling water inlet temperature for the water-cooled undergarment, long, for two clothing ensembles and for two hot environments.

This study will continue with the final water-cooled undergarment (water-cooled undergarment, short, which covers the torso, arms and legs) dressed with the CVC alone and with the CVC plus closed CB suit. Then the two air-cooled systems, one using ambient (hot chamber) air and the other using air-conditioned air will be dressed on the sectional manikin with the two clothing ensembles. When this sectional manikin phase of the auxiliary cooling study is completed, those auxiliary cooling systems which appear to show the most promise will be examined in a hot chamber physiological study using human test subjects.

LITERATURE CITED

Fonseca, G. F. Effectiveness of four water-cooled undergarments and water-cooled cap in reducing heat stress. Aviat. Space Environ. Med. 47:1159-1164, 1976.

Program Element:	6.27.77A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness, and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Commercial Medical Hot and Cold Packs
Investigators:	John R. Breckenridge and Clement A. Levell

Background:

In 1978, a request was received from Defense Logistics Agency (DLA) for evaluation of two commercial items, a chemical heating pad and a chemically-activated cold pack, for possible application as items of medical issue; these items had been submitted to DLA for its consideration by Product Design, a distributor located in Tucson, Arizona. Results of the assessment of the heating pad, based on its heat production capabilities, were reported last year. The pad produced 3.1 watts maximum after mixing the chemicals, which decreased to 0.8 watts after "deactivated" storage for two weeks; the maximal output was not considered sufficient to maintain manual dexterity for a relatively inactive man in ambient temperatures below -25°C (-13°F), even when the hand was protected by an Arctic mitten. Accordingly, this chemical heating pad was judged to have little merit as an item of medical issue.

Progress:

The second item, the chemically-activated cold pack, was evaluated by following the temperature depression at the surfaces of this plastic pouch after the two chemicals, a powder and a liquid, had been mixed. For temperature measurements, two thermocouples were attached to the upper surface and two to the under surface of the pouch. After mixing the chemicals, temperatures were recorded at 1-minute intervals for 10 minutes, and then at 5-minute intervals for an additional 90 minutes. Measurements were made at two air temperatures, 40°C (104°F) and 27°C (80°F), using one sample at each condition.

In 40°C air, the surface fell to 15°C (59°F), average, one minute after mixing then began rising, reaching 20°C after 5 minutes. In 27°C air, average surface temperature dropped to 14.8°C one minute after mixing and rose 0.5°C by the fifth minute. Neither pouch showed any evidence that the contents had frozen. It was concluded that the cold pack would provide little benefit in the treatment of sprains, etc. which, combined with its bulkiness, made its appeal as a field medical item quite low.

Reports summarizing the findings regarding the heating pad and cold pack have been forwarded to Defense Logistics Agency for their guidance. DLA was advised that neither item met the manufacturer's claims, and that neither item was considered of value as a medical survival item.

Program Element:	6.27.77A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Miitary Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Five Marine Corps Footwear Systems
Investigator:	John R. Breckenridge

Background:

The U.S. Marine Corps has made contractual arrangements, through USANARADCOM, with USARIEM to measure sectional insulating values of USMC combat and ski boots worn with and without a vinyl overshoe. The primary purpose of this work was to learn how much the overboot would improve insulation and improve acceptability of these footwear items at low temperatures.

Progress:

Five footwear systems, plus a sixth to show the effect of wearing a saran insole in the combat boot, were measured on the 12-section copper foot. As shown in Table 1, the sectional and overall insulating values for the combat boot were virtually unaffected by the sock (cushion sole or wool ski) worn. As expected, the saran insole improved only the insulation under the sole, increasing it 20%, from 0.92 to 1.10 clo, for the foresole (under the toes, which are the most critical and most difficult foot areas to protect). The overshoe worn with either the combat boot or ski boot increased insulating values for most sections, and afforded considerably improved protection for the more critical foot areas, namely, the toes, instep and heel, which fall in temperature most rapidly during inactive cold exposure. A report summarizing the findings has been forwarded to the Marine Corps through USANARADCOM. This report pointed out the problems of using the overshoe with the ski boot, i.e., that the gripping effect of the ski boot tread is completely lost when it is covered by the overshoe.

TABLE 1. Insulating Values of Marine Corps Footwear Systems

(clo units)

Combat boot with:

Section	Cushion Sole Sock	Cushion Sole Sock, Saran Insole	Ski Sock, Saran Insole	Ski Sock, Saran Insole, Vinyl Overshoe
Achilles	0.99	0.99	0.96	1.18
Heel	1.07	1.08	1.05	1.20
Instep	1.01	1.01	1.15	1.53
Sidewall (outer)	0.99	1.01	1.03	1.32
Sidewall (inner)	1.23	1.19	1.19	1.51
Toecap	0.70	0.68	0.67	0.85
Foresole	0.92	1.10	1.08	1.39
Midsole	1.37	1.47	1.47	1.97
Overall	1.01	1.03	1.05	1.30

Chippewa Ski Boot #326 with:

Section	Ski Sock, Felt Insole	Ski Sock, Felt Insole Vinyl Overshoe
Achilles	1.64	1.71
Heel	1.38	1.51
Instep	1.39	1.82
Sidewall (outer)	1.51	1.76
Sidewall (inner)	2.00	2.16
Toecap	0.92	1.04
Foresole	1.86	2.01
Midsole	2.32	2.57
Overall	1.51	1.71

Program Element: 6.27.77A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness, and Medical Factors in Military Performance

Work Unit: 048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments

Study Title: Evaluation of Combat Vehicle Clothing Uniform Systems

Investigators: Clement A. Levell, Ralph F. Goldman, Ph.D. and Leander A. Stroschein

Background:

Clothing, Equipment, and Materials Engineering Laboratory (CEMEL) of USANARADCOM is in the process of developing a new Combat Vehicle Crewman's (CVC) Uniform for wear primarily in the cold-wet environs of Europe, to replace the standard cold wet uniform currently being worn by CVC personnel. This uniform will include either an 8 or 16 ply Kevlar ballistic vest. CEMEL has requested copper manikin evaluation of various CVC systems incorporating new items for the CVC system to obtain a basis for estimating the effect of item additions on the insulating value and evaporative transfer characteristics of the uniform. Additionally, this Institute has been tasked with evaluation of the summer weight CVC uniform, with and without such items as a face mask or Kevlar armor.

Progress:

Copper manikin assessments of 9 combinations of items for the summer and winter CVC systems have been completed. These combinations have been selected to show the effects on insulating value (clo) and evaporative heat transfer potential (i_m/clo) of adding a face mask or Kevlar vest (8 and 16 ply versions) to the basic summer uniform; similar separate effects of adding overalls, a face mask, a balaclava, or Kevlar vest were established for the winter CVC uniform.

Components used in the 9 CVC ensembles, and the insulation (clo) and

evaporative transfer (i_m/clo) characteristics determined on the manikin are given in Table 1.

Results of the measurements show the following:

Summer Uniform:

1. Adding a face mask increases insulation from 1.75 to 1.81 clo and lowers i_m/clo from 0.25 to 0.22 (b vs a).
2. An 8-ply vest increases clo value from 1.81 to 1.91, and lowers i_m/clo by 0.01 (c vs b).
3. Changing to a 16-ply vest alters clo value by about the same amount as an 8-ply vest but lowers i_m/clo from 0.22 to 0.19 (d vs b).

Winter Uniform:

1. Addition of overalls increases clo value from 3.03 to 3.55, lowers i_m/clo from 0.13 to 0.10 (f vs e).
2. The clo value with a face mask measured slightly lower than without (probably a dressing variable) and i_m/clo was unaffected (g vs f).
3. An 8-ply vest added 0.25 clo but did not affect i_m/clo (h vs g).
4. A 16-ply vest added 0.20 clo, and lowered i_m/clo from 0.10 to 0.09 (i vs g).

A predictive analysis using USARIEM modeling techniques remains to be completed. Predictions of heat and cold stress in terms of such factors as activity level, environment, and CVC clothing system worn will be made to provide guidance regarding tolerance time for field tests to be conducted in Germany during Winter 1979-80. Marine Corps will perform additional testing of the uniform in Europe.

Table 1. CVC Systems Evaluated

Ensemble Items*

Ensemble	Under-Wear	Boots	Vest	Bala-clava	Face Mask	Gloves	Jacket	Overalls
a)	SU	SB				SG		
b)	SU	SB			X	SG		
c)	SU	SB	8 ply		X	SG		
d)	SU	SB	16 ply		X	SG		
e)	WU	WB		X		WG	X	
f)	WU	WB		X		WG	X	X
g)	WU	WB			X	WG	X	X
h)	WU	WB	8 ply	X	X	WG	X	X
i)	WU	WB	16 ply	X	X	WG	X	X

*All ensembles included coveralls and helmet

SU - Summer Underwear (cotton drawers and T-shirt)
WU - Winter Underwear (50/50 2 piece long johns)
SG - Summer Glove (high temperature resistant knit)
WG - Winter Glove (high temperature resistant knit with high temperature resistant insulation)
SB - Summer Boot (single ply leather)
WB - Winter Boot (double ply leather with insulation)

Copper Manikin Results

Summer Uniform

	clo	i_m	i_m/clo
a)	1.75	.43	.25
b)	1.81	.40	.22
c)	1.94	.40	.21
d)	1.92	.36	.19

Winter Uniform

	clo	i_m	i_m/clo
e)	3.03	.39	.13
f)	3.55	.35	.10
g)	3.43	.36	.10
h)	3.68	.37	.10
i)	3.63	.33	.09

Program Element:	6.27.77A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness, and Medical Factors in Military Performance
Work Unit:	048 Biomedical Impact of Military Clothing and Equipment Design Including the Selection of Crew Compartment Environments
Study Title:	Evaluation of Korean Military Clothing Systems
Investigator:	Clement A. Levell

Background:

Based on the Joint U.S. Military Assistance Group - Korea Data Exchange Agreement, the Korean Government has requested that a biophysical, copper manikin assessment of their military clothing be conducted. Performance of this work by this Institute has been arranged under a USANARADCOM contract; the scope of the work consisted of evaluating insulation (clo) and evaporative heat transfer (i_m/clo) characteristics of ensembles made up of from 5 to 9 layers and hence allowed Institute personnel to obtain information on the effects of layering insofar as it affects heat and moisture transmission.

Progress:

Evaluation of the 8 clothing ensembles supplied by the Korean Government has been completed. A listing of the components employed is given in Table 1 and their arrangement in the various systems in Table 2. Some difficulties were experienced in obtaining sufficiently large items to fit the copper manikin, whose dimensions are based on the anthropometry of U.S. military personnel rather than of the smaller Korean soldier. In particular, the Korean handwear and footwear items were so small that they could not be used. A single set of U.S. combat boots and gloves was used on the manikin in place of the Korean items listed for the respective ensembles.

Results of the evaluations are presented in Table 3. The insulation values range from 2.94 clo, approximately the same as for the U.S. Cold-Wet Uniform, to 3.90 clo, slightly less than for the complete U.S. Cold-Dry Uniform (4.3 clo).

The moisture permeability index values (i_m) are as high, or slightly higher than for U.S. cold weather ensembles, indicating effective heat dissipation by sweating (nearly optimal cooling for this type of clothing under the low air movement at which measurements were made). Results for certain of the ensembles are misleading owing to an extremely tight fit on the copper man. In particular, the i_m values for systems E123 and E212 (0.30) are believed to be lower than the others because the clothing was so tight it could barely be closed. This tightness eliminated air layers which normally exist between clothing layers and prevented the development of convection currents which augment the vapor transfer process. None of the layers in these two systems had vapor-resistant characteristics per se, and could not have been responsible for the low values of vapor permeability (i_m) which were obtained.

TABLE 1

List of Clothing Items for Test

Symbol	Items
A	Shorts, Cotton, White
UB2	Drawers, Cotton
UC2	Drawers, W/A
UD1	Undershirt, W/C
UD2	Drawers, W/C
UE2	Drawers, Wool
F1	Shirt, Field, HBT
F2	Trousers, Field, HBT
V	Vest, Cold Weather
LG1-1	Liner, Coat, G-1
LG2-1	Liner, Trousers, G-1
LG1-3	Liner, Coat, G-3
LG2-3	Liner, Trousers, G-3
LS1-1	Liner, Coat, S-1
LS2-1	Liner, Trousers, S-1
LS1-2	Liner, Coat, S-2
LS2-2	Liner, Trousers, S-2
LS1-3	Liner, Coat, S-3
LS2-3	Liner, Trousers, S-3
LP1-1	Liner, Parka, E-1
LP1-2	Liner, Parka, E-2
LP2	Liner, Trousers, Ex
OG1	Coat, GN
OG2	Trousers, GN
OS1	Coat, SP
OS2	Trousers, SP
PA1	Parka, Lx
PA2	Trousers, Ex

Continued:

List of Clothing Items for Test

Symbol	Items
BM	Boot, CV
BS	Boot, SP
BG	Boot, GN
BC	Boot, Combat
MK	Mitten, Knitted-Inserts
MP	Mitten, Pile-Inserts
GL	Glove, Shells, Leather
SP	Socks, PR
SL	Socks, Long
CA	Cap, Cold Weather
K	Mask, Cold Weather
NS	Scarf, Neckwear
	Socks, U.S. Cushion Sole
	Boots, U.S. Combat
	Gloves, U.S.

TABLE 2: KOREAN CLOTHING SYSTEM COMPONENTS

(See Table 1 for descriptions)

System Designations	G121		G211		S123		S211		E123		E212		S122		E322	
Body Area	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper	Lower
Layer 1	UB 1	A UB 2	UD 1	A UD 2 SP	UB 1	A UB 2	UD 1	A UD 2 SP	UB1	A UB 2	UD 1	A UD 2 SP	UB1	A UB 2	UB 1	A UB 2
Layer 2	UC 1	UC 2 SP	F1	F2	UC 1	UC2 SL	F 1	F 2	UC1	UC2 SL	F 1	F 2	UC1	UC 2	UC 1	UC 2
Layer 3	F 1	F 2	V NS		F 1	F 2	V NS		F1	F 2	V NS		UE1	UE 2 SL	UE 1	UE 2 SL
Layer 4	V NS		K CA LG1-1	LG2-1	V NS		K CA LS1-1	LS2-1	V NS	LS2-3	K CA LS1-2	LS2-2	F 1	F2	F1	F 2
Layer 5	K CA LG1-1	LG2-1	OG1 GL	OG2 BG	K CA LS1-3	LS2-3	OS 1 MK	OS 2 BM	K CA LS1-3	LS2-3	OS 1	OS 2	V NS		V NS	
Layer 6	OG 1 MK	OG 2 BC			OS1 MP	OS2 BS			OS1	OS 2	LP1-1	LP2-1	K CA LS1-2	LS2-2	K CA LS1-2	LS2-2
Layer 7									LP1-2	LP2-2	PA 1 MK	PA 2 BM	OS 1 MP	OS 2 BS	OS 1	OS 2
Layer 8									PA1 MP	PA2 BS					LP1-2	LP2-2
Layer 9															PA1 MP	PA2 BS

TABLE 3

Insulation (clo) and Vapor Transfer (i_m/clo) Characteristics of Korean Clothing Systems

System*	clo	i_m	i_m/clo
G121	3.18	.40	.13
G211	3.11	.42	.14
S123	3.05	.35	.11
S211	2.94	.37	.13
E123	3.65	.30	.08
E212	3.68	.30	.08
S322	3.03	.44	.15
E322	3.90	.41	.11

*See Table 2 for components

1. TITLE (Precede with Security Classification Code)* (U)Prevention and Treatment of Disabilities Associated w: Military Operations at High Terrestrial Elevations (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

012600 Pharmacology; 005900 Environmental Biology; 013400 Physiology

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
70 07	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousa
FISCAL YEAR	PRECEDING 79	7	304
	CURRENT 80	7	322

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* BURSE, Richard L., Sc.D.

TELEPHONE: 955-2893

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: YOUNG, Andrew J., Ph.D., CPT, MSC

NAME: CYMERMAN, Allen, Ph.D.
MAHER, John T., Ph.D. DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Acute Mountain Sickness; (U)Exercise at Altitude; (U)Energy Expenditure; (U)Muscle Strength; (U)Load Carriage; (U)Target Detection

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Exposure of soldiers to high terrestrial elevations results frequently reduced military performance as well as medical disabilities which are incompatible wi the successful completion of military operations. The purpose of this work unit is characterize these performance decrements and disabilities and to investigate the bas of and methods for their prevention and treatment.

24. (U) Studies will be conducted in man to (1) determine the mechanisms of the physi logic alterations and medical disabilities at altitude; (2) assess and predict t performance of individuals and small units operating at altitude; (3) evaluate t efficacy of pharmacolgical agents and other means in preventing or reducing performan decrements and illness; (4) enhance the rate of adaptation to high terrestrial elev tions.

25. (U) 78 10 - 79 09 (1) The severity and duration of acute mountain sickness (AMS) we not reduced by pretreatment with phenytoin, despite its documented ability to decrea sodium in brain cells; (2) Isometric and isokinetic strength of several skeletal musc groups of soldiers was unimpaired during 48 hours of sojourn at 4575 meters simulat altitude; (3) Soldiers who hyperventialted during fatiguing isometric exercise at s level did not show enhanced resting ventilation at 4,300 meters and did not suffer le from (AMS); (4) Threshold luminance for detection of military targets was direct related to target size and viewing distance and rose significantly during the first t days at 4300 meters, followed by progressive recovery under sustained exposure; (Endurance time was not altered during 7 days at 4300 meters in soldiers carrying a 30 backpack up a 16% grade; (6) A model developed for the prediction of energy expenditu at sea level was shown to be inapplicable to work at high elevations.

*Available to contractors upon originator's approval.

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations

Study Title: Pharmacological Adjunct to High Altitude Exposure

Investigators: Richard L. Burse, Sc.D., John T. Maher, Ph.D., Milton Landowne, M.D., Allen Cymerman, Ph.D., Andrew J. Young, CPT, MSC, Ph.D.

Background:

Among the medical problems associated with abrupt exposure to high altitude are acute mountain sickness (AMS), high altitude pulmonary edema, cerebral edema and retinal hemorrhage. By far the most common form of altitude illness is AMS which is characterized by headache, insomnia, gastrointestinal symptoms and lassitude. Mild symptoms occur in some individuals at elevations as low as 2500 meters, whereas at 4500 meters symptoms are almost invariably present, often to the degree that a fully-trained soldier is incapable of caring for himself.

Staging, a temporary residence at an intermediate altitude prior to ascent to a higher one, is an effective method of protecting against the symptoms of AMS. However, the military requirement for troops to be rapidly deployed to high elevations may not allow the several days that staging requires in order to induce partial acclimation. The logistics of transporting troops to intermediate elevations and the availability of appropriate staging sites within CONUS also make this procedure unrealistic. Acetazolamide has been found to be useful in ameliorating symptoms when given before and continued during initial exposure. However, in addition to the requirement for pretreatment, this drug superimpses a metabolic acidosis to counteract the respiratory alkalosis of hypoxia, and it is not completely effective in preventing symptoms (1-3). Hence the need remains to seek understanding of the mechanism of AMS and to devise superior prevention and therapy.

Because the etiology of AMS has not been established, efforts to treat the

disorder have been symptomatic by necessity. Studies of body fluid volumes and distribution have reported decreases in extracellular fluid volume (4,5,6) without significant change in total body water (5,6). Hansen and Evans (7) have hypothesized that the basic cause of headache and other neurological features of AMS is brain edema. Fishman (8) has reported on the role of failure or impairment of the ATP-dependent sodium pump mechanism within cells consequent to oxygen deprivation in the production of brain edema. Sodium rapidly accumulates within cells and water follows to maintain osmotic equilibrium. Singh and his colleagues (9) noted cerebral edema at necropsy of two patients with severe AMS and in two others brain tissue bulged through burr holes when trephining was done to relieve increased intracranial pressure.

The present study seeks to evaluate the effectiveness of phenytoin sodium (Dilantin®) in preventing or ameliorating the symptoms of AMS. Among the well-documented actions of phenytoin is an ability to decrease the intracellular concentration of brain sodium (Na) and increase the ratio of extra-to-intracellular brain Na (10). The mechanism by which phenytoin acts to reduce brain Na has not been established although evidence suggests that it may stimulate metabolic processes involved in the active extrusion of Na from brain cells. In the case of hypoxia in which high-energy phosphates in brain are depleted (11,12), phenytoin may be expected to elevate brain "energy reserve" compounds (13,14) and, in turn, restore function of the ATP-dependent sodium pump.

Progress:

A preliminary study was performed on 6 male volunteers to assess the effect of phenytoin on the occurrence and severity of AMS symptoms in response to acute hypoxic exposure at 4575 meters in the USARIEM hypobaric chamber. The study was of double blind design. Half the subjects received phenytoin at a dosage of 0.1 g at 8-hour intervals and the other half placebo (lactose, USP) for one day prior to and during 2 days of altitude exposure. Ten days later the procedure was repeated, with administration of placebo and phenytoin reversed among subjects. Phenytoin dosage was intended to provide serum concentrations between 10 and 15 $mcg \cdot ml^{-1}$ during altitude exposure. Measured serum concentrations ranged from 4.4-13.9 $mcg \cdot ml^{-1}$, as shown in Table 1.

TABLE 1

Phenytoin Serum Concentration Levels ($mcg \cdot ml^{-1}$)
During Altitude Exposure. Subjects Primed for
18 Hours Prior to Initial Exposure

	Hours of Altitude Exposure		
Subject	2	26	50
1	10.5	6.0	10.1
2	7.4	M	M
3	7.2	6.2	4.1
4	4.4	M	M
5	9.1	6.7	W
6	9.1	8.1	13.9 M*

*Value at 36 hours, just after medical withdrawal from exposure
M = Withdrawn by medical monitor
W = Voluntarily withdrew from exposure

Results of the clinical evaluations showed that phenytoin had no markedly beneficial effects on the occurrence, severity or duration of AMS symptomatology. Table 2 shows the peak severity of symptoms as reported by subjects over the period of exposure. As symptom questionnaires were administered only in mid-morning and mid-afternoon, symptoms which peaked at other times were not reported. This had little effect on interpreting the data, as subjects who vomited or who voluntarily withdrew from the exposure can be presumed to have been suffering from AMS symptoms. Overall, one subject appeared to benefit from phenytoin, one was about the same and two were worse, subject 5 reporting more severe symptoms and subject 4 vomiting with phenytoin, but not with placebo. Two subjects' results were very difficult to interpret. Subject 3 displayed less severe symptoms but withdrew from the exposure with placebo. Subject 6 had more severe symptoms with phenytoin, but may have been suffering from a mild upper respiratory infection at that time. In addition, he

seemed to be acutely sensitive to hypoxia, as he exhibited a dulled affect during both altitude exposures which may have affected his subjective ratings of symptom severity. Comparison of serum concentrations with symptomatolgy shows that the 3 highest levels were in subjects 5 and 6 with high symptom severity and in subject 1 with the lowest. This indicates no tendency for a dose-response relationship, at least within this range of serum concentrations.

TABLE 2

Peak Severity of Symptoms for Each Subject when Phenytoin (Ph) or Placebo (Pl) were Administered for 18 Hours Prior to and Throughout 2 Days of Altitude Exposure

	1		2		3		4		5		6	
Symptom	Ph	Pl	Ph	Pl	Ph	Pl	Ph	Pl	Ph	Pl	Ph	Pl
Sleeplessness	0	0	1	0	2	2	0	3	3	2	1	0
Am tired	0	0	0	1	1	2	0	1	3	2	1	0
Difficulty concentrating	0	1	0	1	1	1	0	0	3	0	1	1
Headache	0	1	3	3	3	1	1	3	3	2	3	1
Dizziness	0	1	0	1	3	1	0	0	3	1	3	0
Weakness	0	0	0	0	3	1	0	0	3	1	3	1
Upset stomach	0	0	3	3	3	0	0	3	3	0	0	0
Nausea	0	0	3	3	3	0	0	0	3	0	3	0
Feel sick	0	1	3	3	3	0	0	0	3	0	2	0
Other	-	-	V,M,	V,M	-	W	V,M	-	W	-	M*	-
Ph effect	better		same		equivocal		worse		worse		equivocal	

Severity code: 0 = none, 1 = slight, 2 = moderate, 3 = severe

"Other" code: V = vomited, W = voluntarily withdraw from altitude exposure

M = withdrawn from altitude exposure for medical reasons

*Subject may have had upper respiratory infection

An attempt was made to assess the effect of phenytoin on cognitive and psychomotor processes. Map reading tasks showed no differences with phenytoin and a radio message transcribing and decoding task suffered so much from the altitude exposure per se that useful results were not obtained. Gas mask donning and doffing times were not affected by phenytoin. A tracking task sensitive to both time and distance off-target was administered, but the resultant analog data on magnetic tape are now awaiting completion of the computer system and program for their analysis.

Ventilatory parameters of respiratory rate and depth, minute ventilatory volume, end-tidal P_{O_2} and P_{CO_2} and respiratory phase and phase-dependent cardiac sinus arrythmia were measured and await detailed analysis.

The ventilatory parameters will be analyzed to determine their relationships to phenytoin administration and symptom severity. This will be done in order to assess whether or not phenytoin adversely affected ventilatory responses at altitude and thereby exerted its adverse effects on symptomatology. In addition, the tracking task data will be analyzed and their relationship to symptom severity established in order to add to the data base of the effect of AMS on military performance tasks.

Since phenytoin showed no markedly beneficial effect in reducing AMS symptomatology (and indeed may have made it worse), further testing of this drug appears unwarranted at this time.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations
Study Title:	Ventilation during Isometric Exercise at High Altitude
Investigators:	Richard L. Burse, Sc.D., Allen Cymerman, Ph.D., Andrew J. Young, CPT, MSC, Ph.D., James E. Wright, CPT, MSC, Ph.D. and John T. Maher, Ph.D.

Background:

The severity of acute mountain sickness (AMS) symptomatology has been shown to be inversely related to the extent of the ventilatory response to high-altitude hypoxia (1,2): the greater the increase in ventilation, the less the severity. Neither individual susceptibility to AMS nor the ventilatory response to altitude exposure is predictable prior to hypoxic exposure. Those individuals especially predisposed to AMS who may burden medical treatment or evacuation facilities can be identified now only after exposure to altitude or to hypoxic gas mixtures in the laboratory. Consequently, it would appear very useful to have a simple predictive test to be given prior to ascent that may estimate an individual's ventilatory response to altitude hypoxia and possibly his susceptibility to AMS.

Such a test might be readily developed. In two sets of experiments, Wiley and Lind (3,4) have explored the ventilatory response to fatiguing isometric exercise. When either arm (handgrip) or leg (extensor) exercise at submaximal levels was performed to complete fatigue of the involved muscles, minute ventilatory volume ($\dot{V}_E$) was found to increase, markedly so in some individuals. The marked increase in $\dot{V}_E$ represented true hyperventilation, as the end-tidal P_{CO2} dropped while the ventilatory equivalent ($\dot{V}_E/\dot{V}O_2$) increased. The hyperventilation stops almost immediately upon termination of the exercise (3). Further, the hyperventilation in response to isometric fatigue could be superimposed upon the hyperpnea of concurrent dynamic exercise (4). These findings suggest a neurally-mediated control mechanism for the response. The observed

ventilatory increase showed wide variability between individuals (from 4 to 40 liters•min^{-1}) and might represent the degree of sensitivity of the respiratory centers to peripheral neural afferents. If so, then ventilatory sensitivity to fatiguing isometric exercise might also indicate the sensitivity of the acute ventilatory response to hypobaric hypoxia, which is also neurally mediated by the peripheral chemoreceptors.

The ventilatory response during fatiguing isometric exercise at sea level can be compared to the initial and subsequent ventilatory response to altitude exposure and to the severity of AMS symptomatology, to test the hypothesis that individuals who exhibit a marked hyperventilatory response to fatiguing isometric exercise at sea level (responders) will also show a greater hyperventilatory response at altitude both at rest and during isometric exercise. Responders should also manifest AMS symptoms of less severity than non-responders.

If this hypothesis is correct, then a simple screening procedure of the type specified could serve to identify soldiers with greater or lesser risk of AMS when exposed to altitude. Such a procedure could be used to select responders to receive mountain training, to identify non-responders as potential AMS casualties in high-altitude unit operations, or to separate those individuals who require acclimatory staging at intermediate elevations from those who might be able to proceed directly to high elevations. High-risk individuals could be assigned responsibilities near routes of medical evacuation, while lower risk individuals could be preselected for wide-range operations.

Progress:

The strength, endurance and ventilatory responses to four trials of isometric handgrip exercise separated by 11-15 min were determined on five separate days at sea level in 13 male volunteer soldiers. Handgrip at 40% of the maximum voluntary contraction (determined from the highest of three brief maximal exertions 60 sec apart) was maintained on a handgrip dynamometer (5) until complete fatigue occurred (until the target gripping force could not be maintained any longer), with grip durations from 1 to 3 min. Appropriate precautions were taken to insure the subjects only utilized a single muscle group throughout the duration of the exercise; the general technique was as previously described (3,5,6).

Ventilatory parameters of minute ventilatory volume, oxygen uptake and CO_2 production were measured before, during and after each contraction by on-line pneumotachographic spirometry of expired air with concurrent analysis of O_2 and CO_2 concentrations by fuel cell and infrared analyzers, respectively.

Following the baseline testing sea level, subjects were transported to Pikes Peak (4300 meters) for a 7-day stay. Retesting was performed on the second and sixth day at altitude to determine ventilation, handgrip strength and handgrip endurance both early and late in the altitude exposure. The study was of a repeated measures design, with each subject serving as his own control. Ventilatory parameters were compared at sea level and after 2 and 6 days at altitude, and also to the AMS symptomatology reported at altitude. The AMS symptoms were assessed by specific items from the Environmental Symptoms Questionnaire (ESQ) (7) evaluating presence and degree of headache, light-headedness and dizziness, breathing difficulty, nausea, vertigo, tiredness and insomnia.

The original data pool of 13 subjects was reduced by the exclusion of one subject because of serious doubt about the veracity of his ESQ symptom ratings and the voluntary withdrawal of another at the end of day 2, leaving a total pool of 12 subjects on day 2 at altitude and 11 on day 6. By day 2, 6 subjects had indicated one or more symptoms by which they clearly could be judged to have been suffering from moderate to severe AMS, and who formed the SICK group. Of the remaining 6 subjects, 4 indicated no AMS symptoms other than slight to moderate headache and 2 had symptoms indicative of only mild AMS; these formed the "not very sick" or WELL group. By day 6, the SICK group size had been reduced to 5 (all but 1 of whom were nearly well), while the WELL group remained intact and was essentially asymptomatic. The symptomatology for each subject on the the last day of testing at sea level is shown in Table 1a, on day 2 of altitude exposure in Table 1b and on day 6 of exposure in Table 1c.

With the exception of subject 4 who had not slept well the night before, the subjects at sea level showed the usual assortment of minor ailments that are the expected "background" symptomatology in a group this size. By day 2 at altitude, most symptomatology was markedly elevated in those considered to have moderate to severe AMS, but was particularly high for the items related to headache and stomach upset. The group considered to be not very sick had fewer symptoms than the SICK group, as well as less severe symptoms. By day 6, most

subjects were at or below their sea level symptomatology. Again, subject 4 showed the highest levels of symptomatology, related to his inability to get enough sleep.

TABLE 1a

AMS Symptomatology Displayed at Sea Level.
Classification as SICK or WELL Based upon Later Altitude Exposure.

	SICK GROUP						WELL GROUP					
SYMPTOM / Subject Number	1	2	3	4	5	6	7	8	9	10	11	12
Headache	0	1	0	3	0	0	0	0	0	0	0	0
Head throbbing	0	1	0	3	0	1	0	0	0	0	0	0
Light-headed	0	0	0	4	0	0	2	0	0	0	0	0
Faint	0	0	0	2	0	0	0	0	0	0	0	0
Hard breathing	0	0	0	0	0	0	0	0	0	0	0	0
Nausea	0	1	0	0	0	0	1	0	0	0	0	0
Upset stomach	0	2	0	0	0	2	1	0	0	0	0	0
Weakness	0	1	0	5	0	1	1	0	0	0	0	0
Vertigo	0	0	0	0	0	0	1	0	0	0	0	0
Tired	0	1	2	4	0	1	2	0	0	0	0	0
Insomnia	0	0	2	5	0	0	0	0	0	0	0	0

0 = none, 1 = slight, 2 = somewhat, 3 = moderate, 4 = severe, 5 = very severe

TABLE 1b

Peak AMS Symptomatology on Days 1 and 2 of Exposure to 4300 Meters Altitude by Classification into SICK and WELL Groups

SYMPTOM	SICK GROUP						WELL GROUP					
Subject Number	1	2	3	4	5	6	7	8	9	10	11	12
Headache	4	5	1	4	5	4	1	0	1	1	0	0
Head throbbing	4	5	0	4	5	4	2	0	1	0	0	0
Light-headed	3	3	2	3	5	2	2	1	1	0	0	0
Faint	1	3	2	2	1	2	2	0	0	0	0	0
Hard breathing	2	3	3	1	0	0	0	1	0	0	0	3
Nausea	2	3	5	1	5	1	0	0	1	0	0	0
Upset stomach	3	3	5	1	5	1	0	0	1	0	0	0
Weakness	2	3	4	1	3	2	2	1	1	0	0	1
Vertigo	1	2	3	1	3	2	2	0	0	0	0	0
Tired	1	3	5	1	4	3	2	0	0	0	0	0
Insomnia	4	5	5	3	5	4	0	1	0	0	2	0

0 = none, 1 = slight, 2 = somewhat, 3 = moderate, 4 = severe, 5 = very severe

TABLE 1c

AMS Symptomatology on Day 6 of Exposure to 4300 Meters Altitude by Earlier Classification into SICK and WELL Groups

SYMPTOM	SICK GROUP						WELL GROUP					
Subject Number	1	2	3	4	5	6	7	8	9	10	11	12
Headache	WITHDREW	0	1	3	0	0	0	0	0	0	0	0
Head throbbing		0	0	2	0	0	0	0	0	0	0	0
Light-headed		0	0	1	0	0	0	0	0	0	0	0
Faint		0	0	1	0	0	0	0	0	0	0	0
Hard breathing		0	2	0	0	0	1	0	0	0	0	0
Nausea		0	0	0	0	0	0	0	0	0	0	0
Upset stomach		0	0	0	0	0	0	0	0	0	0	0
Weakness		0	0	3	0	0	2	0	0	0	0	0
Vertigo		0	0	1	0	0	1	0	0	0	0	0
Tired		0	0	4	0	0	1	0	0	0	0	0
Insomnia		3	1	5	0	0	2	1	0	0	0	0

0 = none, 1 = slight, 2 = somewhat, 3 = moderate, 4 = severe, 5 = very severe

Peak minute ventilatory volumes during the 4 endurance handgrips or in the first minute of recovery are shown in Table 2. The absolute values, the absolute changes and percentage changes from sea level to day 2 at altitude and from day 2 to day 6 at altitude are indicated. The peak ventilatory rates were similar for all 4 handgrips in both the SICK and WELL groups. The groups had almost identical mean values at sea level (range 28-40 liters•min^{-1}), on day 2 at altitude (range 35-46) and for grips 2-4 on day 6 at altitude (range 45-55), with the maximum difference being only 8 liters•min^{-1}. Grip 1 on day 6 at altitude was 13 liters•min^{-1} (or 26%) higher in the SICK than in the WELL group, but this difference disappeared in the second through fourth grips. It is clear that the peak ventilation was increased above that at sea level on day 2 at altitude. The overall average was increased 17% in the SICK group and 19% in the WELL group. There was an even greater increase in peak ventilation from day 2 to day 6 at altitude of 23% in the SICK group and 24% in the WELL group. Clearly, both groups respond to altitude in an identical manner and the hypothesis of being able to discriminate between them by their peak ventilatory responses to fatiguing exercise must be rejected. However, the increase in peak ventilatory response upon initial altitude exposure and a further increase with prolonged exposure have not been reported heretofore. Further analysis of the relative changes in resting ventilation and their comparison to the responses during exercise must be performed in order to see if there is a difference in the ventilatory sensitivity to hypoxia at rest and in isometric exercise.

TABLE 2

Peak Minute Ventilatory Volume ($\dot{V}_E$, $\ell\cdot min^{-1}$) during Fatiguing Isometric Handgrip Exercise or in the First Minute of Recovery. SICK and WELL Groups as shown in Table 1b. G1 = Grip Number 1, G2 = Grip Number 2, etc.

	SICK (n=6)				WELL (n=6)			
CONDITION	G1	G2	G3	G4	G1	G2	G3	G4
Sea Level	34	36	36	37	32	28	40	35
Day 2 Alt.	46	40	37	44	41	35	41	43
Δ	+12	+4	+1	+7	+9	+7	+1	+8
(Δ%)	(+35)	+11)	(+3)	(+19)	(+28)	(+25)	(+3)	(+23)
Day 6 Alt.	62*	45*	47*	52*	49	49	55	45
Δ	+16	+5	+10	+8	+8	+14	+14	+2
(Δ%)	(+35)	(+13)	(+27)	(+18)	(+20)	(+40)	(+34)	(+5)

*n=5

Table 3 shows the maximum isometric grip strength at sea level and on days 2 and 6 of altitude exposure for the pool of 11 subjects. There was an overall increase of 12% after 2 days' altitude exposure and an additional increase of 4% with four more days' exposure. These increases were significant at the $p < 0.01$ level when tested by analysis of variance. There was a corresponding decrease in isometric endurance time on day 2 of exposure for grip 2 (significant at $p < 0.05$) and a somewhat larger decrease for grip 4 (significant at $p < 0.01$). However, there was not a corresponding decrease in endurance time on day 6 of exposure. In fact, there was a slight gain, if anything, during grip 4 but the difference was not significant. Similar gains in strength upon altitude exposure have been found by Young and Wright of this Institute (unpublished data) and together they pose interesting problems for understanding the control of muscle function. As the data analysis from this study is only beginning, exciting prospects lie ahead.

TABLE 3

Maximum Isometric Grip Strength and Endurance of 4 Fatiguing Handgrip Contractions at Sea Level and on Days 2 and 6 at Altitude. N=11, G1=Grip Number 1, etc.

CONDITION	Strength (kg)	Duration (seconds) G1	G2	G3	G4
Sea level	60	115	96	87	82
Day 2 Alt.	67	105	80	75	64
Δ	+7	-10	-16	-12	-18
(Δ%)	(+12)	(-9)	(-17)	(-14)	(-22)
Day 6 Alt.	70	102	84	76	70
Δ	+3	-3	+4	+1	+6
(Δ%)	(+4)	(-3)	(+5)	(+1)	(+9)

Further analysis of the muscle strength and endurance data are warranted by these preliminary results and have already been started. The initial results concerning the relationship of peak ventilatory rates to AMS symptomatology are most disappointing from the viewpoint of gaining a predictor of AMS susceptibility. However, the control of ventilation under hypoxic conditions is now becoming better understood (8), and the increased ventilation during isometric exercise must be examined in order to see if it indicates an altered hypoxic sensitivity.

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations

Study Title: The Effect of Hypobaric Hypoxia on the Strength and Endurance of Local Muscle Groups

Investigators: Andrew J. Young, CPT, MSC, Ph.D., James E. Wright, CPT, MSC, Ph.D., Allen Cymerman, Ph.D. and SP6 Joseph J. Knapik

Background:

Humans acutely exposed to hypoxia suffer impairment of cardiovascular and pulmonary functions and a decrement in aerobic work capacity (1,2,3). Little information is available regarding the effects of hypoxia on the strength capacity of skeletal muscle. Despite this paucity of information, descriptions of acute mountain sickness (AMS) (4,5) usually include the symptom of "muscle weakness" or "*fatigue*." Thus, the goal of this study was to quantitatively evaluate the effects of acute exposure to altitude (hypobaric hypoxia) on muscle strength and strength endurance. In addition, the relationship, if any, between the onset and severity of AMS and strength alterations at altitude would be examined.

The importance of muscle strength in the total fitness of today's soldier is undetermined. Recent MOS task analysis conducted jointly by TRADOC, USAIS, and USARIEM (6) suggests that strength is a significant factor in all Army MOSs and perhaps a limiting aspect of performance in 25-30% of MOSs (mainly in combat and combat support jobs). Contingency plans may provide for rapid deployment of troops to areas of the world at considerable elevations above sea level; thus, a need exists for evaluation of the potential effects of this environment on the soldier's muscular strength.

There have been both anecdotal (7) and theorectical (1,8) suggestions that muscle strength might be affected by oxygen lack, perhaps via the central or peripheral branches of the nervous system. Recent research in this area has

considered only the handgrip muscles, and only brief exposures to hypoxia have been investigated. The data are contradictory. A study by Kaijser (9) demonstrated a decrement in dynamic muscular performance. Bowie and Cumming (10) have reported no change in static muscular performance when inspired oxygen was 12% and an increase in performance when inspired oxygen was 9%. In both cases performance was the length of time subjects could continue muscle contraction and not the force exerted during muscle contraction.

Progress:

Initially, skeletal muscle strength of ten subjects was assessed at sea level on three consecutive days. At least seventy-two hours later the subjects were placed in a hypobaric chamber which was then decompressed to a simulated altitude of 4,572 meters. Muscle strength was then assessed after two (HA1), twenty-four (HA2) and forty-eight hours (HA3). The subjects were then released from the chamber. After at least forty-eight hours of rest, strength was assessed a final time.

Muscle strength assessment included measures of both static and dynamic strength of various muscle groups. Maximal voluntary strength of the upper torso (arms and shoulders), leg extensors, and trunk extensors was measured using a device designed by the Exercise Physiology Division, USARIEM (11). Dynamic muscle strength of the right knee extensors was measured using an isokinetic dynamometer (Cybex Division, Lumex Corp., Bay Shore, NY). Dynamic strength was measured at velocities of 0, 36, and 180 degrees per second. Strength was recorded as peak force exerted (kilograms) in the case of static measures or peak torque exerted (Newton-meters) in the case of dynamic measures. Strength endurance of the knee extensors was measured during a sixty-second bout of repeated isokinetic contractions at 180 degrees per second. The peak torque exerted during every other contraction was recorded and used to compute the regression equation of peak torque against contraction number. The slope of the regression line was used to describe strength endurance.

Results of static and dynamic strength assessment are shown in Table 1. Initial sea-level data showed no significant differences and are represented as a single mean value for each measurement. There were no significant differences

between strength at sea level and strength after two or twenty-four hours of hypobaric hypoxia. After forty-eight hours, however, all six strength measures were elevated relative to sea-level values and the difference (12%) was statistically significant in the case of static arm strength. The increase in strength averaged approximately 8% for all six measures.

TABLE 1

Effect of Hypobaric Hypoxia on Maximal Skeletal Muscle Strength

Measurement	Pre-Exposure	HA1	HA2	HA3	F	P Level
Static Strength (kg) Arm	87.3	89.6	86.4	98.9*	3.28	< .05
Static Strength (kg) Leg	126.6	111.3	125.0	137.1	5.40	< .01
Static Strength (kg) Trunk	73.9	70.1	64.2	81.1	3.18	< .05
Isokinetic Strength (Nm) Leg (180°/sec)	121.6	120.1	118.1	128.5	1.41	N.S.
Isokinetic Strength (Nm) Leg (36°/sec)	181.2	185.9	183.7	189.4	0.32	N.S.
Isokinetic Strength (Nm) Leg (0°/sec)	199.0	197.0	207.8	215.8	1.00	N.S.

Values shown = mean (n=8)

*Significantly different from pre-exposure (Dunnett's test)

Table 2 shows the mean of the three strength assessments made prior to the hypoxic exposure and the strength assessments made at sea level after forty-eight hours of rest. Five of the six measures were higher after the exposure and differences were significant in two cases.

TABLE 2

Maximal Skeletal Muscle Strength Before and After 48-Hour Exposure to Hypobaric Hypoxia

	Pre -Exposure	Post -Exposure
Static Strength (kg) Arm	87.3	95.0*
Static Strength (kg) Leg	126.6	133.9
Static Strength (kg) Trunk	73.9	81.8*
Isokinetic Strength (Nm) Leg (180°/sec)	121.6	132.5
Isokinetic Strength (Nm) Leg (36°/sec)	181.2	196.8
Isokinetic Strength (Nm) Leg (0°/sec)	199.0	198.6

Values shown = mean (n=8)

*Significantly different from pre-exposure at $p < .05$

The regression of peak torque against contraction number fits a linear model reasonably well; the correlation coefficient (r) averaged 0.9 for all trials. There were no significant changes in the regression equation.

Results of analysis of the symptomatology questionnaire are shown in Table 3. After twenty-four and forty-eight hours, there was a significant increase in the reports of symptoms. (Note the high percentage of subjects reporting the symptom "weakness" at these times). These results are in agreement with other AMS symptomatology analyses (4).

TABLE 3

Number of Subjects Experiencing the Symptom

Expressed as a Fraction of Total Number of Subjects

Symptom	Pre-exposure	HA1	HA2	HA3	Post-exposure
Muscle tense	.30	.10	.50	.13	.10
Muscle ache	.37	.10	.50	.13	0
Headache	.10	.10	1.00	1.00	.40
Headthrob	.10	.10	1.00	1.00	0
Nauseous	.20	.20	.90	.75	0
Weakness	.20	.20	.90	.75	.20
Tired	.20	.30	.60	.50	.50
Trouble sleeping	.03	.20	.90	1.00	.20
Clumsy	0	.30	.60	.63	0
Mean	.17	.19	.77†	.65†	.16
Number of respondents	10	10	10	8	10

*Symptom scores taken prior to each of the three pre-exposure strength tests showed no significant differences allowing the three scores to be represented by a mean score for each symptom.

†Significantly different from pre-exposure value ($p<.05$).

The results of this study indicate that acute exposure to hypobaric hypoxia imposed no detriment to muscle strength, even at a time when AMS was most pronounced. In fact, the results of the study raise the possibility that muscle strength may be enhanced if hypoxic exposure were continued beyond forty-eight hours.

Field studies will be carried out at the USARIEM facility located at the summit of Pikes Peak (4300 meters). In these studies the results of this chamber study will be verified. In addition, at this field laboratory it will be possible to study muscle strength alterations during an altitude exposure of longer duration than is possible in the hypobaric chamber. The relationship, if any, between the increased activity of the sympathetic nervous system at altitude and muscle strength will also be investigated.

Presentations:

Young, A. J., J. E. Wright, J. J. Knapik, J. Scelza and A. Cymerman. the effect of altitude exposure on skeletal muscle strength in man. Presented, Annual Meeting of the American College of Sports Medicine, Honolulu, HI, 23-26 May 1979. Med. Sci. Sports 2:88, 1979.

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations

Study Title: Skeletal Muscle Strength and Urinary Catecholamines during a Seven-Day Sojourn at High Altitude

Investigators: Andrew J. Young, CPT, MSC, Ph.D., James E. Wright, CPT, MSC, Ph.D., Allen Cymerman, Ph.D., Richard L. Burse, Sc.D. and John T. Maher, Ph.D.

Background:

In a prior study reported elsewhere in this Annual Report, skeletal muscle strength was evaluated after two, twenty-four, and forty-eight hours of continuous exposure to hypoxia in a hypobaric chamber. Results indicated that muscle strength was unimpaired at these times, although after twenty-four and forty-eight hours of exposure acute mountain sickness (AMS) was most pronounced. Furthermore, the data suggested that after forty-eight hours strength may have been somewhat elevated. Thus one goal of the present study was to determine if the results of the previous chamber study would be replicated at an actual high altitude location. The effect of increased duration of high altitude sojourn on muscle strength was also to be investigated. Finally, urinary catecholamine excretion rate was measured throughout the study in an attempt to determine if changes in catecholamine excretion (a measure of sympathetic nervous system activity (1)) were related to any strength alterations or AMS symptomatology experienced by the subjects during the sojourn.

Progress:

Skeletal muscle strength was assessed three times at sea level and four times atop Pikes Peak (elevation 4300 meters). Successive strength assessments were separated by twenty-four hours and the altitude sojourn took place approximately three weeks after the sea-level phase of the study. All strength

assessments included nine strength measures: upper torso, knee extensor, and trunk extensor static strength; isokinetic (0^{o}, 36^{o}, and 180^{o} per sec) strength of left elbow flexors and knee extensors.

In addition to the strength measures, urinary catecholamine excretion and AMS symptomatology were measured during the study. Twenty-four hour urine production was collected from the subjects for four days at sea level and seven days during the altitude sojourn. Epinephrine and norepinephrine excretion were determined from aliquots of these collections. The Environmental Symptoms Questionnaire (ESQ) of Kobrick and Sampson (2) was used to assess AMS symptomatology every morning during the sojourn. Subjects completed this questionnaire by rating the degree to which they experienced each of 55 symptoms. The rating scale was from 0-5 where 0=not at all and 5=extreme.

Data analysis is not yet complete. Some preliminary analyses, however, have been completed. Norepinephrine excretion increased at altitude becoming significantly different from sea-level excretion on the fourth day at altitude (day four excretion approximately double sea-level value). Epinephrine excretion showed no statistically significant change during the altitude sojourn. These results are in accordance with other studies previously reported (3). Table 1 shows the values for catecholamine excretion rate.

TABLE 1

Urinary Catecholamine Excretion (μg/24 h)

		Day at Altitude						
	Sea Level	1	2	3	4	5	6	7
Norepinephrine	48.0	41.1	58.6	72.6	93.5*	75.2	86.1	93.6*
Epinephrine	8.6	8.0	7.5	9.1	15.1	12.8	14.9	14.1

Values represent means (n=8)

*Significantly different from sea level value ($p < .05$)

Preliminary analysis of the ESQ showed AMS symptomatology to be most

prevalent on the first morning of the sojourn and remitting thereafter. This would indicate that these subjects responded to altitude exposure in a rather typical manner. The relationship between catecholamine excretion and AMS will be further investigated. Table 2 shows the percentage of subjects experiencing six selected symptoms of AMS. The data from the muscle strength testing is not yet analyzed.

TABLE 2

Number of Subjects Experiencing the Symptom Expressed as a Fraction of the Total Number of Subjects

Symptom	SL	1	2	3	4	5	6	7
Headache	.13	.75	.63	.63	.38	.25	.25	.25
Headthrob	.13	.25	.38	.25	.13	.13	.13	0
Nauseous	.13	.38	.13	0	0	0	0	0
Weakness	.38	.75	.50	.50	.38	.38	.38	.38
Tired	.50	.50	.50	.38	.38	.38	.25	.25
Insomnia	.38	.25	.38	.50	.38	.38	.38	.38
Mean	.28	.48	.42	.38	.28	.25	.23	.22

Data analysis will be completed. Results and conclusions drawn from this study will be prepared in the form of a manuscript for publication. There are no further plans to continue this line of investigation.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations
Study Title:	Effects of Hypoxia on the Luminance Threshold for Target Detection
Investigator:	John L. Kobrick, Ph.D.

Background:

Since many military operations are conducted at twilight or at night to minimize detection, a number of military tasks involve the ability to detect and recognize enemy targets at low illumination levels. Although hypoxia is known to impair dark adaptation (1,2,3), the data are based on the detection of simple light flashes. Effects of environmental stress on the acquisition and perception of complex meaningful military targets is unknown. The present task was designed to determine threshold luminance values for detection and recognition of selected military targets as a function of viewing distance.

The experimental task involved viewing a series of projected slides of military target objects (vehicles and personnel) such that the images subtended at the retina duplicated real-life image sizes for three viewing distances (60, 90, 120 yards). Subjects adjusted the image brightness by manipulating a variable density filter to achieve the threshold brightness for detection and for recognition for each target and viewing distance condition.

Progress:

Data were obtained for nine male soldiers who performed the task at normal sea level conditions and subsequently at two-day intervals during exposure to high elevation (4,300 m) in a field study conducted at Pikes Peak, CO. The group mean luminance thresholds for target detection (log millilamberts) across the period of exposure are shown separately for each viewing distance in Figure 1. Sizable increases in detection thresholds are

evident between sea level and first performance at high elevation, (2 days of exposure) and appear to be in rough proportion to the viewing distances involved. In general, the data seem to indicate an initial peak impairment, followed by gradual recovery, which follows the pattern of other types of perceptual performance data obtained during altitude exposure in previous studies.

An analysis of variance performed on the individual luminance threshold detection values indicated that the main effects of viewing distance and target size, as well as their simple interaction, were highly significant ($p < .001$). However, the altitude main effect was not significant, despite the performance trends apparent in Figure 1. Since this finding was inconsistent with the early threshold increases observable in Figure 1, multiple paired Student's t tests were calculated to compare the sea level threshold values with those obtained at altitude. The results of these tests are summarized in Table 1. It can be seen that significant increases in group mean thresholds had occurred by the second day at altitude, which, in fact, increased in value directly with viewing distance. However, there was a progressive reduction of impairment with continued hypoxia, which by the sixth day was no longer significantly different from sea-level performance. It would appear, then, that hypoxic exposure did result in a significant elevation of the luminance threshold for target detection, which peaked on the second day and recovered thereafter. Also, threshold luminance values reflected the target sizes involved in a logical manner, i.e., smaller targets required higher luminance values for detection than did larger targets.

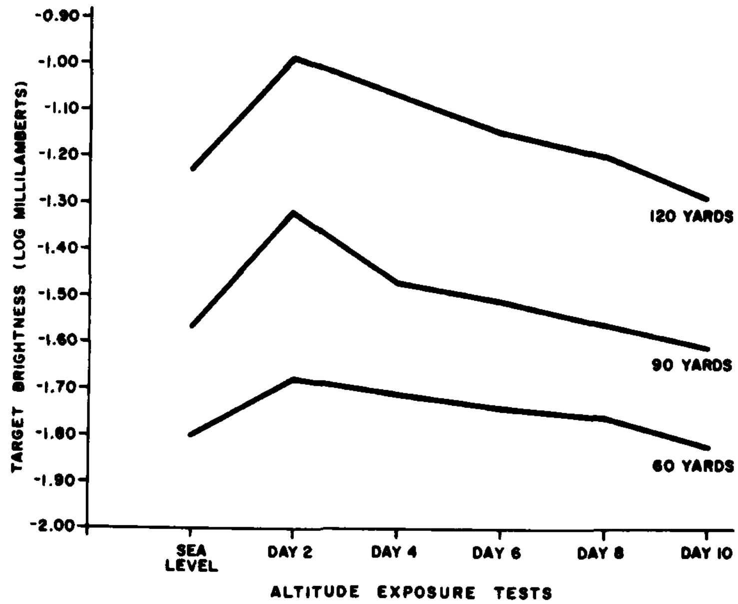

Figure 1. Group mean threshold luminance for target detection as a function of viewing distance at each testing session.

TABLE 1

Summary of Paired Student's t Tests of Daily Mean Differences in Threshold Luminance for Target Detection

Source		t	DF	P
Sea level - Altitude Day 2	60 yards distance	3.19	34	< .01
	90 yards distance	3.68	34	< .01
	120 yards distance	4.37	34	< .01
Sea level - Altitude Day 4	60 yards distance	2.05	29	< .05
	90 yards distance	.90	29	NS
	120 yards distance	2.16	28	< .05
Sea level - Altitude Day 6	60 yards distance	1.36	29	NS
	90 yards distance	1.18	29	NS
	120 yards distance	.62	29	NS

A manuscript reporting this work is in preparation. Plans are in progress to compare performance on the present task at altitude with dark adaptation thresholds obtained with a new night vision testing device developed at LAIR.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project.	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations
Study Title:	Prediction of the Severity of Acute Mountain Sickness Using a Simple Ventilatory Test at Sea Level
Investigators:	Allen Cymerman, Ph.D. and Andrew J. Young, CPT, MSC, Ph.D.

Background:

Exposure to high altitude causes an acute self-limiting illness termed acute mountain sickness (AMS) characterized by such nonspecific symptoms as headache, nausea, lassitude, and insomnia. One characteristic of AMS is the variability in occurrence and severity with which it affects different individuals. This variability may be related to the individual's ventilatory response to hypoxia. This hypothesis has been tested by several investigators (1,2) with the general observation that an inverse correlation exists between the increase in ventilation and AMS severity. Since minute ventilation is the combination of tidal volume and the respiratory frequency, it may be possible to differentiate the change in ventilation due to a hypoxic stimulus into either a change in frequency or a change in tidal volume, or both. The purpose of this study is to determine whether a simple determination of hypoxic ventilation can be used to predict AMS severity in subjects subsequently exposed to high altitude.

Progress:

One month before ascent to Pikes Peak, ventilatory responses were measured in two groups of subjects (group 1 = 7 subjects; group 2 = 6 subjects). The men breathed either humidified air or a hypoxic gas mixture (humidified 12% O_2, 88% N_2) while respiratory rate, tidal volume, and minute ventilation were recorded. Ear oximetry was used to monitor "arterial" oxyhemoglobin levels. Prior to and daily during altitude exposure subjects completed a 52-item questionnaire designed to assess the presence and severity of AMS.

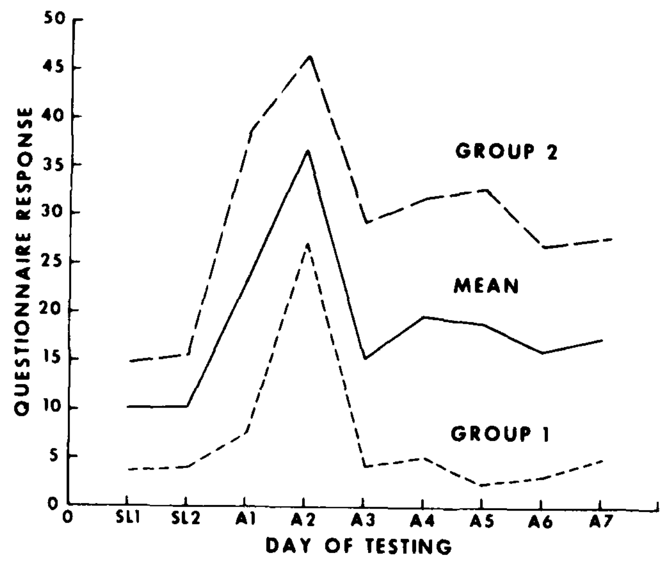

Figure 1. Severity of AMS symptoms at sea level (SL) and altitude (A) indicated by responses on an environmental symptom questionnaire.

Figure 1 illustrates the severity of AMS in both groups of subjects as a function of time at high altitude. It is noteworthy that despite different sea-level baseline values, the pattern of response was similar in both groups. AMS severity peaked on day 2 and subsided thereafter.

Table 1 lists the variables that were compared with the individual altitude symptom scores. Spearman rank-order correlation was used to test for significance. The only variable that was significantly correlated with the severity of reported symptoms ($p < 0.05$) was the change in frequency of breathing, i.e., those subjects reporting the worst symptoms altered their breathing frequency the least during the ventilatory test.

TABLE 1

Changes in Several Ventilatory Parameters During a 5-Min Hypoxic Test

Subject	Δ% HbO_2	Δf (min^{-1})	ΔTV (ℓ)	Δ$\dot{V}_E$ (ℓ•min^{-1})
1	7	-0.3	0.3	1.7
2	8	1.0	0.2	3.3
3	13	0.0	0.1	2.3
4	8	-3.0	1.6	5.6
5	12	4.5	-0.4	8.2
6	8	4.3	0.3	7.9
7	9	0	0.4	2.4
8	11	1.7	0.0	1.4
9	9	-2.4	0.6	4.5
10	10	-1.3	0.2	2.8
11	9	0.0	0.1	1.4
12	18	0.3	0.1	1.4
13	11	-1.7	0.1	0

Δ = difference between normoxic and hypoxic conditions

Test conditions consisted of 5 min of normoxia and 5 min of hypoxia ($12\%\ O_2$, $88\%\ N2$)

The hypoxic ventilatory test will be administered to a larger number of subjects in order to increase the reliability of prediction.

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations

Study Title: Self-Paced Exercise at High Altitude

Investigators: Allen Cymerman, Ph.D., Andrew J. Young, CPT, MSC, Ph.D., Richard L. Burse, Sc.D., James E. Wright, CPT, MSC, Ph.D. and John T. Maher, Ph.D.

Background:

The inhospitality of the high-altitude environment in which the US Army may be asked to perform requires that each individual in a unit be self-sufficient with regard to survival. This is true at least during the early phases of operations when reinforcements and resupply are least available. The load of survival items is a detriment in that it must be physically carried, contributing greatly to fatigue and possible incapacitation. Assuming that the load is relatively fixed, there is an optimum rate of walking that will not exhaust an individual prior to reaching the objective in a fixed-distance march.

The energy expenditure associated with load carriage while walking at sea level has been studied extensively (1,2), and some work has been done at altitude (3,4). These reports propose a concept of a fixed-energy cost per kg of total weight for movement at specific speeds and grades. Dynamic work is feasible without appreciable fatigue at 35-50% of maximal aerobic capacity. However, considering the 15-20% reduction in maximal aerobic capacity that occurs at 4300 m altitude and the changes in perception during work at high altitude (5), it is likely that the self-paced work rate is markedly altered at altitude and that sea level estimates are inappropriate. This study was initiated to determine the changes, if any, in the voluntary rate of walking a 3-mile distance with continued exposure to 4300 m altitude.

Progress:

A one-man treadmill was modified so that its speed was controlled by the subject. A pushbutton switch controlled the speed of the treadmill while the subject walked 4.8 km (3 mi) carrying a balanced 30-kg standard Army backpack. While walking, subjects breathed through a mouthpiece interfaced with appro priate transducers and an on-line computer which calculated oxygen uptake, carbon dioxide production, and ventilation every minute. Maximal oxygen uptake was determined at sea level and on the fourth day of altitude exposure using a standard modified Balke treadmill test.

Two 7-man groups of Army volunteers were initially recruited for the two-month study. Subjects were tested twice at sea level at least 2 weeks prior to altitude exposure and after 1, 3, and 7 days residence at Pikes Peak (4300 m). One subject was dropped from the altitude phase for medical reasons, and two subjects voluntarily withdrew at altitude due to severe symptoms of acute mountain sickness.

All data have been collected and are currently being statistically analyzed.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations
Study Title:	Effects of Altitude Exposure on Energy Expenditure During Physical Work
Investigators:	Allen Cymerman, Ph.D., Kent B. Pandolf, Ph.D., Andrew J. Young, CPT, MSC, Ph.D., John T. Maher, Ph.D. and Thomas J. Kinane, LTC, MC, M.D.

Background:

The soldier in the field often encounters terrain variations which may sharply curtail his work performance. This is especially true at high terrestrial elevations where the reduced oxygen partial pressure results in a lower maximal oxygen uptake (1) and a lower endurance capacity (2). A theoretical model for predicting the energy cost to the soldier of walking at various speeds and grades has been developed at sea level (3). However, the model has not been tested under hypoxic conditions which impose a physiological limit to the work output.

Submaximal oxygen consumption at the same absolute work load is unchanged at different altitudes (4). Thus, with increasing work loads at sea level or altitude, oxygen consumption increases linearly until a maximum is obtained. Increasing the weight a soldier must transport will result in a further increase in oxygen consumption or energy expenditure assuming the constancy of such factors as mechanical efficiency and load placement.

The prediction formula devised for sea level work (3) was tested at 4300 m altitude for its predictive capability:

$$M = 1.5\,W + 2.0\,(W+L)\,(L/W)^2 + (W+L)\,(1.5V^2+VG)$$

where M = watts, W = body weight, L = load, V = walking velocity, and G = grade. While the additional weight carriage will force a soldier to work at an oxygen consumption level closer to his maximum, this prediction equation should still be valid at high altitude.

Progress:

Eight Army male volunteers were recruited. One week prior to altitude exposure at Pikes Peak (4300 m) maximal oxygen uptakes were determined on each subject at sea level and 4300 m simulated altitude in a hypobaric chamber.

While in residence at Pikes Peak, subjects walked with pack loads ranging from 0 to 30 kg on grades from 0 to 16% on days 1, 5, and 9 for a maximum of 10 min or until voluntary termination. Oxygen uptake was measured every 15 sec using an on-line computer system which sampled expired O_2, CO_2, and air volume. Three subjects either voluntarily withdrew from the study or were removed for medical reasons.

Table 1 illustrates the physical characteristics of the subjects and their maximal oxygen uptakes. Subjects lost 2% of their body weight during the exposure despite ample food availability. On the average, maximal oxygen uptake was reduced 16%.

TABLE 1

Physical Characteristics

Subject	Age yrs	Height cm	Weight kg	% Fat	Sea Level $\dot{V}_{O_2}$ max $ml \cdot kg^{-1} \cdot min^{-1}$	Altitude $\dot{V}_{O_2}$ max $ml \cdot kg^{-1} \cdot min^{-1}$
1	19	181	78.9	18.8	37.8	33.3
2	20	171	87.9	24.7	36.6	29.3
3	18	181	84.7	17.7	47.8	37.9
4	21	179	88.4	22.6	41.9	30.3
5	20	178	63.1	15.2	47.1	37.3
Mean	19.6	178.2	80.6	19.8	42.2	3[illegible].6
S.E.	0.5	1.8	4.7	1.7	2.3	1.7

Table 2 shows the endurance times for the two most difficult work loads. Of the 15 sessions at each of these work loads only 7 subjects were able to complete 10 min with the 15 kg load at 16% grade and only one subject managed to complete a single session with the 30 kg load at 16% grade. There were no changes in endurance times with continued altitude exposure.

TABLE 2

Endurance Time (min) for the Two Extreme Work Loads at Altitude

Subject	Load (kg)/Grade (%)	
	15/16	30/16
1	7.58	3.34
2	5.51	4.13
3	10.00	5.48
4	4.71	2.17
5	8.83	5.69
Mean	7.33 min	4.16 min
S.E.	0.99	0.66

The results of the physiological responses are shown in Table 3. work rates ranged from 4206 to 8057 kg•m•min^{-1} at 0% grade. Increases in heart rate are more apparent with changes in grade than with load. Heart rate changed approximately 8 beats•min^{-1} when the load was increased from 0 to 30 kg. An increase of 43 beats•min^{-1} was observed when grades were increased from 0 to 16%. The relatively greater effect of grade is also evident with the other physiologic variables.

TABLE 3

Physiological Responses of 5 Subjects Working at 67.2 m•min^{-1} (2.5 mph) for Different Work Loads at 4300 m Altitude

External Load kg	Grade %	Work Rate kg•m•min^{-1}	Heart Rate beat•min^{-1}	$\dot{V}O_2$ (STPD) ml•kg•min^{-1}	$\dot{V}_E$ (BTPS) l•min^{-1}	Oxygen Pulse ml•beat^{-1}
0	0	—	120 ± 5	10.46 ± 0.31	29.43 ± 0.98	7.20 ± 0.25
0	8	440 ± 25	143 ± 5	17.57 ± 0.50	52.77 ± 2.98	9.96 ± 0.72
0	16	880 ± 50	165 ± 6	27.48 ± 0.57	94.55 ± 7.56	14.14 ± 1.25
15	0	—	129 ± 5	11.51 ± 0.29	33.28 ± 0.86	7.22 ± 0.22
15	8	520 ± 25	153 ± 6	18.67 ± 0.46	60.66 ± 3.97	10.36 ± 0.90
15	16	1041 ± 50	172 ± 7	26.99 ± 1.03	113.69 ± 8.13	12.75 ± 1.15
30	0		129 ± 6	12.79 ± 0.36	39.72 ± 1.61	7.99 ± 0.65
30	8	601 ± 25	152 ± 6	22.69 ± 0.70	78.79 ± 6.17	11.80 ± 0.95
30	16	1202 ± 50	170 ± 5	29.61 ± 1.48	128.91 ± 7.65	14.66 ± 1.17

Figure 1 illustrates the relative changes in $\dot{V}O_2$ as a function of load and grade. The greater influence of grade on $\dot{V}O_2$ is shown. The effect of grade on $\dot{V}O_2$ is 5.5 times greater than load.

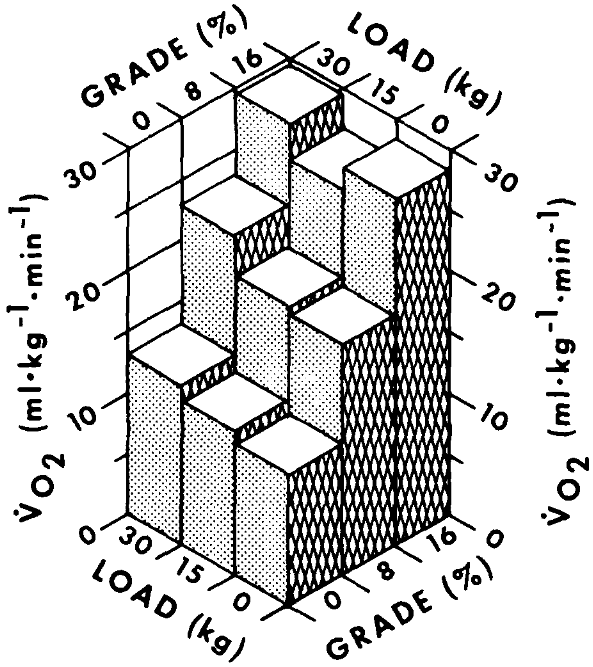

Figure 1. Relative effects of changing external load and treadmill elevation on steady-state oxygen uptake.

Table 4 illustrates the mean energy expenditure at each of the work loads. The relative effect of increases in grade versus external load is also illustrated.

TABLE 4

Mean Energy Expenditure (W) for All Tested Loads and Grades

Grade (%)	Applied Load (kg) 0	15	30
0	298 $\pm$ 18	322 $\pm$ 18	361 $\pm$ 23
8	507 $\pm$ 44	536 $\pm$ 40	633 $\pm$ 46
16	733 $\pm$ 98	754 $\pm$ 49	750 $\pm$ 61

Values are presented as Mean $\pm$ S.E. Actual energy expenditure is based on applied load plus body weight.

Using the prediction equation mentioned previously, actual versus predicted energy expenditure is plotted in Figure 2. Least squares regression produced the equation $y = 1.32\,x - 125$ with a correlation coefficient of 0.98. Repeated measures analysis of variance of the difference between actual and predicted values indicated that the two lines are significantly different. The difference becomes apparent (except for one point) at an energy expenditure above ~ 550 W. This is equivalent to about 1.6 $l \cdot min^{-1}$ oxygen uptake. Using the bicycle ergometer estimates of maximal oxygen uptake, this value is comparable to 47% of the subjects' sea-level maximal uptakes and 55% of their altitude maximal uptakes. Thus, the prediction equation (3) derived empirically at sea level, does not correspond well with values obtained at altitude when work loads produce oxygen uptakes which exceed 50% of maximal oxygen uptake.

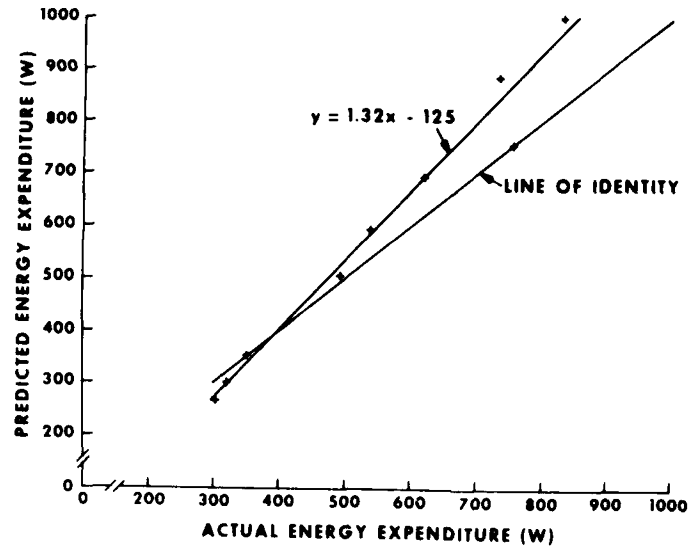

Figure 2. Actual and predicted energy expenditure (ref. 3) for walking with external loads (0-30 kg) and grades (0-16%) at 4300 m altitude.

As a point of comparison, Nag et al. (5) suggested an optimal work rate for highlanders and porters at high altitude of 4000 kg•min•$^{-1}$ (25-30 kg actual load at 3-3.5 km•h^{-1}). This work rate was only 30-40% of the maximal work capacity of their subjects and corresponds to a 25% higher work rate than the 0 kg load-0% grade condition studied here. Thus, even in good physical condition and with partial acclimatization, the average US Army soldier cannot compare in work output with high altitude natives.

All subjects, however, completed all 10-min sessions at work loads of 8% grade and external loads of 30 kg. This represents approximately 633 W or 3800 kg•m•min^{-1}, a work rate that could be sustained for 10 min with appropriate rest periods and is higher than the suggested voluntary "maximum hard work" rate of 3000 kg•m•min^{-1} (6).

An abstract and manuscript are currently in preparation. No further investigations are planned in this area.

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6. Hughes, A. L. and R. F. Goldman. Energy cost of hard work. J. Appl. Physiol. 29:570-572, 1970.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	051 Prevention and Treatment of Disabilities Associated with Military Operations at High Terrestrial Elevations
Study Title:	Oxygen Deficit and Debt During Acute Exposure to High Altitude
Investigators:	Allen Cymerman, Ph.D., Kent B. Pandolf, Ph.D., Andrew J. Young, CPT, MSC, Ph.D., Thomas J. Kinane, M.D., LTC, MC and John T. Maher, Ph.D.

Background:

When steady-state submaximal work is performed at altitude, the same oxygen uptake ($ml \cdot kg^{-1} \cdot min^{-1}$) is obtained for the same absolute work load as at sea level. However, it appears that the total volume of oxygen utilized during exercise and recovery is larger at altitude after 4-8 weeks at 3750 m (1). Another report (2) indicates that oxygen debt is smaller after 3 weeks at 3800 m, but the results are presented as percent of maximal oxygen uptake and thus the absolute work load was less for some subjects. Since oxygen deficit and debt are directly proportional to work intensity and duration, these results are not surprising. Knuttgen and Saltin (3) reported a greater oxygen deficit and debt after 4 h at 4000 m when analyzed on absolute terms but not on relative terms. The purpose of this study was to quantify the time course of changes in oxygen deficit and debt during the early phases of altitude acclimatization.

Progress:

Five Army male volunteers were studied at sea level and after 30 h, 6, and 10 days residence at 4300 m. One week prior to actual altitude exposure maximal oxygen uptakes were determined on the bicycle ergometer at sea level and at a simulated altitude of 4300 m. Oxygen deficit and debt were calculated

by analyzing the kinetics of oxygen uptake ($\dot{V}O_2$) during work at 98 W for 6 min on the bicycle ergometer. $\dot{V}O_2$ was measured every 15 s prior to, during, and after exercise. Measurements were terminated when $\dot{V}O_2$ returned for 1 min to within 5% of the resting $\dot{V}O_2$. Figure 1 is a diagrammatic representation of the areas in the $\dot{V}O_2$ curve used to determine deficit, debt, and total oxygen consumed.

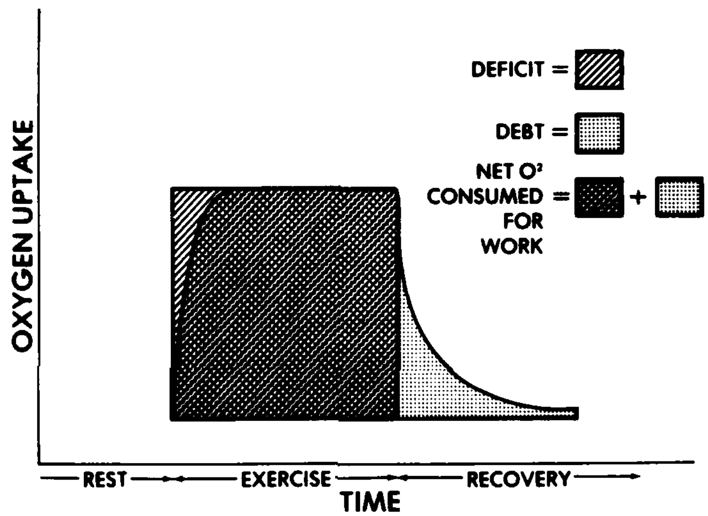

Figure 1. Representation of the areas used for the calculation of oxygen deficit, debt and total oxygen consumed (above resting to perform 8.43 kcal of work on the bicycle ergometer).

Maximal $\dot{V}O_2$ ($\dot{V}O_2$ max), measured at sea level (42.3 ± 2.4 ml•kg^{-1} •min^{-1}, mean $\pm$ SE) and during 4 h simulated altitude (33.8 ± 2.5 ml•kg^{-1}•min^{-1}) was used to determine the relative exercise intensity. Figure 2 indicates that resting heart rates were significantly elevated ($p < 0.05$) during the entire exposure while resting $\dot{V}O_2$ was unchanged.

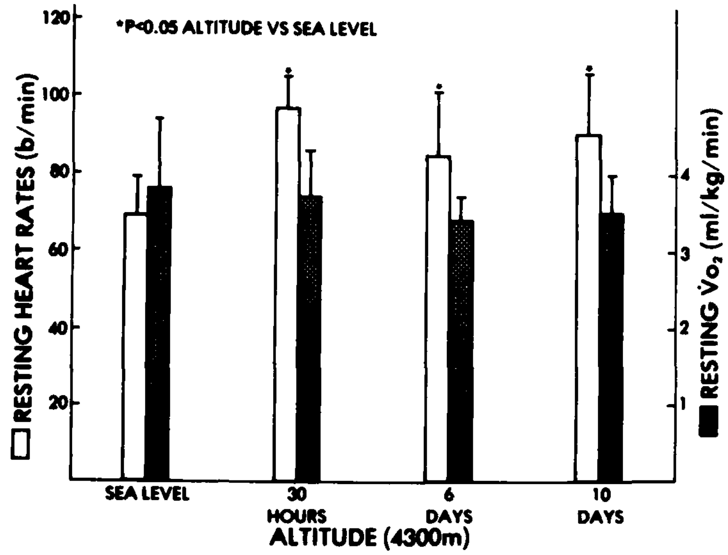

Figure 2. Resting heart rates and $\dot{V}O_2$ determined 10-15 min prior to exercise at 600 kg•m•min^{-1} on the bicycle ergometer at sea level and during 10 days sojourn at 4300 m altitude.

Table 1 illustrates that the steady-state $\dot{V}O_2$ was not altered by altitude exposure. Oxygen deficit and the total oxygen consumed (above resting) were also unchanged at altitude. As a function of relative work intensity, O_2 deficit increased linearly as the % $\dot{V}O_2$ max increased by the relationship: deficit = 0.25 (% $\dot{V}O_2$ max) - 2.3.

TABLE I

Oxygen Utilization During Work at 4300 m Altitude

	Steady-State $\dot{V}O_2$ $ml \cdot kg^{-1} \cdot min^{-1}$	O_2 Deficit $ml \cdot kg^{-1}$	O_2 Debt $ml \cdot kg^{-1}$	Net O_2 Consumed* $ml \cdot kg^{-1}$
Sea Level				
Mean	20.91	12.85	29.51	122
S.D.	2.86	5.32	5.69	12
Altitude $^+$				
Mean	21.99	14.15	22.28^o	123
S.D.	3.23	4.00	4.99	15

Work intensity = 600 $kg \cdot m \cdot min^{-1}$ for 16 min or 8.43 kcal

*Net O_2 consumed = Total O_2 above resting used during exercise and recovery

$^+$Combined value for all altitude measurements

$^o p < 0.02$

Oxygen debt, based on either absolute (Table 1) or relative work intensity (Figure 3), was lower at altitude. Figure 3 also illustrates the higher sea-level debts incurred within the small range of % $\dot{V}O_2$ max values. At altitude this range is increased due to the variable reduction in % $\dot{V}O_2$ max allowing a curve to be plotted.

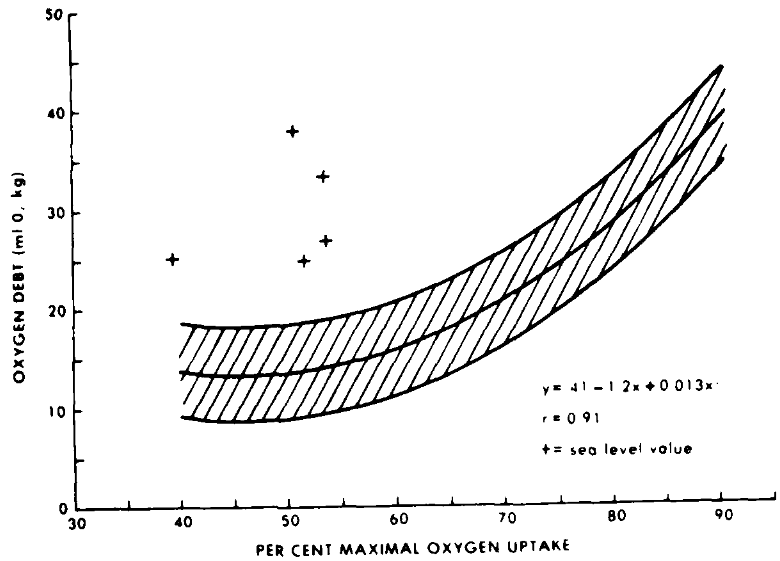

Figure 3. Oxygen debt incurred at 4300 m altitude during and after 6 min of bicycle exercise at 600 kg•m•min^{-1} intensity as a function of % maximal oxygen uptake.

Oxygen debt is considered to be composed of two components: a lactic and an alactic portion. If the alactic component is assumed to remain unchanged at altitude, then these results suggest that the lactic component is responsible for the lower O_2 debt. Since lactic acid production is higher at altitude for a given work load, then it is conceivable that the higher blood lactic acid results in a larger urinary loss and thus less reconversion of lactate to pyruvate. This would result in an apparently lower oxygen debt.

No further effort is contemplated in the area of O_2 deficit and debt at altitude. The present data and conclusions are being prepared for publication.

Presentations and Abstracts:

Cymerman, A., K. B. Pandolf, A. J. Young, T. J. Kinane and J. T. Maher. Oxygen deficit and debt during acute exposure to altitude. Presented, Annual Meeting of the American Societies for Experimental Biology, Dallas, TX, 6-10 April 1979. Fed. Proc. 38:1313, 1979.

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2. Raynaud, J., J. P. Martinaud, J. Bordochar, M. C. Tillous and J. Durand. Oxygen deficit and debt in submaximal exercise at sea level and high altitude. J. Appl. Physiol. 37:43-48, 1974.

3. Knuttgen, H. G. and B. Saltin. Oxygen uptake, muscle high-energy phosphates, and lactate in exercise under acute hypoxic conditions in man. Acta Physiol. Scand. 87:368-376, 1973.

(83053)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY

1. AGENCY ACCESSION*	2. DATE OF SUMMARY*	REPORT CONTROL SYMBOL
DA OB 6148	79 10 01	DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY*	6. WORK SECURITY*	7. REGRADING*	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	D. Change	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:*	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	053
b. CONTRIBUTING				
c. CONTRIBUTING	CARDS 114f			

11. TITLE (Precede with Security Classification Code)* (U)Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing, and Equipment (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS*

016200 Stress Physiology; 013400 Psychology; 011700 Operations Research

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
75 07	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER:* NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	9	353
	CURRENT 80	9	559

19. RESPONSIBLE DOD ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

RESPONSIBLE INDIVIDUAL

NAME: DANGERFIELD, HARRY G., M.D., COL, MC

TELEPHONE: 955-2811

20. PERFORMING ORGANIZATION

NAME:* USA RSCH INST OF ENV MED

ADDRESS:* Natick, MA 01760

PRINCIPAL INVESTIGATOR (Furnish SSAN if U.S. Academic Institution)

NAME:* GOLDMAN, Ralph F., Ph.D.

TELEPHONE: 955-2831

SOCIAL SECURITY ACCOUNT NUMBER:

ASSOCIATE INVESTIGATORS

NAME: PANDOLF, Kent B., Ph.D.

NAME: STROSCHEIN, Leander DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Environmental Tolerance; (U)Performance Limits; (U)Energy Expenditure; (U)Terrain Coefficients; (U)Dehydration

23. TECHNICAL OBJECTIVE,* 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) Develop and validate by physiological studies, mathematical models which synthesize information on military task requirements and the interaction between man, his clothing and equipment, and the environment, to predict mission performance capability and identify areas where additional information is needed.

24. (U) Predictive models of heat production and loss, subjective sensation, and limiting criteria in terms of maximum work capacity as well as unsafe levels of extremity temperature and/or body heat content are evaluated. Systems for predicting individual comfort and unit mission performance decrements and tolerance time are developed from these models. Results are validated in chamber and field trials, involving human volunteers as subjects, and guide clothing and equipment design, suggest tactical doctrine, and indicate potential environmental casualties.

25. (U) 78 10 - 79 09 Radiant heat load (at solar levels) has been studied to permit including its effects in predicting operational tolerance time and/or heat casualties. An improved prediction for water requirements was developed. Male and female responses to work in heat were compared; tolerance depends less on gender than physical fitness ($\dot{V}O_{2\,max}$). Prediction of mobility in the field for units with male and female troops was studied and factors developed. Prediction modelling for cold was improved enough to be put on-line. Studies to recommend safe water temperatures for immersion during training or swamp operations were completed. Work on gas mask effects is being initiated following successful completion of studies on Rescue Breathing Apparatus.

*Available to contractors upon originator's approval

DD FORM 1498, 1 MAR 68 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Energy Cost of Slow Speed Walking and Standing on a Grade

Investigators: Nancy A. Pimental and Kent B. Pandolf, Ph.D.

Background:

Previous work at this Institute has led to the development of a mathematical model which enables prediction of the metabolic cost of walking and standing with loads (1). The energy expenditure prediction formula is:

$$M = 1.5W + 2.0(W + L)(L/W)^2 + \eta (W + L)(1.5V^2 + 0.35VG)$$

where

M = metabolic rate, watt

W = subject weight, kg

L = external load, kg

η = terrain factor, defined as 1.0 for treadmill walking

V = velocity, m s^{-1}

G = grade (slope), %

The energy expenditures of walking at very slow speeds (0.2 to 1.0 m s^{-1}) were all taken on horizontal surfaces (grade = 0%). It seemed desirable to study the effects of walking at very slow speeds on a grade, and also standing on a grade. Grades used were both positive and negative (uphill and downhill).

Progress:

Eight fit male subjects (24 yr, 176 cm, 79 kg) stood, or walked at speeds of 0.5 or 0.9 m s^{-1} for 20-min periods on grades of -10 to +25% with loads of 20 or 40 kg. Energy expenditure (watt) was not significantly different in any of the standing conditions; grade and load increased energy expenditure while standing but not significantly. (See Table 1 for measured and predicted energy expenditure (mean $\pm$ SE) for all conditions.) Although the standing energy expenditure

means were relatively low, high perceived exertion ratings suggest limits to tolerance time in some conditions. All standing means were significantly lower than walking means. Walking 0.9 m s^{-1} on a -10% grade was significantly lower than walking 0.5 m s^{-1} on a +10% grade, which was significantly lower than walking 0.9 m s^{-1} on a +10% grade. While walking, there was a significant difference between loads: means for the 20 kg loads were lower than means for the 40 kg loads. As the condition became more strenuous by increasing load, speed, and/or grade (while walking), energy expenditure became more sensitive to changes in these variables. The current energy expenditure prediction formula (1) was found to predict slightly high for standing conditions, low for walking 0.5 m s^{-1} on a +10% grade, and accurately for walking 0.9 m s^{-1} on a +10% grade. In the standing conditions the deviation between predicted and measured was higher at the 40 kg load than the 20 kg load. The formula is not equipped to predict for negative grades. This study suggests that the prediction formula may place too much emphasis on the effects of speed and load while standing and walking slowly. Future work will include more studies on downhill walking and walking at very slow speeds.

TABLE 1

Measured and Predicted Energy Expenditure Means ± SE for Standing and Walking Slowly on Grades with Loads

Measured Energy Expenditure (watt)	Predicted Energy Expenditure (watt)	Velocity (m s^{-1})	Load (kg)	Grade (%)
112.8 ± 4.8*	131.5 ± 7.1	0.0	20	+10
131.7 ± 5.0*	182.8 ± 3.1	0.0	40	+10
123.1 ± 4.1*	131.5 ± 7.1	0.0	20	+25
136.4 ± 5.3*	182.8 ± 3.1	0.0	40	+25
253.3 ± 7.1		0.9	20	-10
325.1 ± 5.7		0.9	40	-10
385.1 ± 8.2*	345.9 ± 19.0	0.5	20	+10
462.8 ± 8.7*	440.9 ± 14.4	0.5	40	+10
550.3 ± 15.8	558.5 ± 30.6	0.9	20	+10
691.4 ± 12.6	696.5 ± 26.1	0.9	40	+10

*Measured values significantly different form predicted values.

Formula unable to predict for negative grades.

Presentations:

Pimental, N. A. and K. B. Pandolf. Energy expenditure while standing or walking slowly uphill or downhill with loads. The Physiologist 22:101, 1979.

Publications:

Pimental, N. A. and K. B. Pandolf. Energy expenditure while standing or walking slowly uphill or downhill with loads. Ergonomics 22:963-973, 1979.

LITERATURE CITED

Pandolf, K. B., B. Givoni and R. F. Goldman. Predicting energy expenditure with loads while standing or walking very slowly. J. Appl. Physiol. 43:577-581, 1977.

Program Element: 6.27.77A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Comparison of Eccentric and Concentric Muscle Contractions during Various Types of Work

Investigators: Nancy A. Pimental, Kent B. Pandolf, Ph.D. and Yair Shapiro, M.D.

Background:

During concentric contractions the muscle shortens. During eccentric contractions the muscle is being forcibly lengthened. Although the work (force x distance) done by mirror image concentric and eccentric muscle contractions is the same, eccentric contraction is much less than that concentric work (and heart rate is concomitantly lower) as many authors have reported (1-5).

In order to enable us to make predictions for the energy cost of tasks involving eccentric work, data from this study will be used to establish numerical conversion factors for both types of work, since man regularly performs eccentric work: bending, descending stairs, lowering loads, walking and running downhill. Currently there is wide variance in the literature concerning the cost of eccentric as compared to concentric work. Since this may be due to the use of different exercise modes in comparing the two types of work, this study employed two different modes, i.e. walking and cycling, for comparative purposes.

Data on downhill walking also accumulated for use in Pandolf et al.'s energy expenditure prediction formula (6), which takes into consideration subject weight, weight of the load to be carried, speed, type of terrain traversed and grade. The formula can be used to predict the soldier's metabolic rate, and therefore performance and limit times, for a specified mission. Data is needed for walking on a downhill terrain since the formula is not currently equipped to handle negative grades.

Progress:

Eight fit male subjects, capable of heavy load carriage, have been recruited from the test subject pool. Their physical characteristics are (mean $\pm$ s.d.): age, 20.5 $\pm$ 1.4; height (cm), 177.6 $\pm$ 7.2; weight (kg), 70.5 $\pm$ 4.8; and % body fat, 15.1 $\pm$ 3.9. Subjects will be asked to walk on the treadmill, forward or backward, on grades ranging from -15 to +10%, at speeds up to 3-1/2 mph, carrying loads up to 30 kg (66 lbs). On the bicycle ergometer subjects will pedal forward or backward against a resistance at work loads similar to those obtained by walking on the treadmill. The number of conditions totals 61; subjects will be asked to do 3, 20-minute runs a day for 21 days. Heart rate and ratings of perceived exertion will be measured during the runs, and energy expenditure will be determined from analysis of expired air samples.

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6. Pandolf, K. B., B. Givoni and R. F. Goldman. Predicting energy expenditure with loads while standing or walking very slowly. J. Appl. Physiol. 43:577-581, 1977.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing, and Equipment
Study Title:	Troop Mobility of Men and Women as a Function of Load and Terrain
Study Sub-Title:	Voluntary Hard Work Rate of Males and Females
Investigators:	Fred R. Winsmann, William J. Evans, Ed.D. and Kent B. Pandolf, Ph.D.

Background:

Troop units in a maneuver or combat operation often are required to traverse a variety of terrain at self-paced rather than fixed-pace velocities to accomplish an assigned mission. Tactical considerations sometimes dictate troop movement through heavy brush, as well as most other types of terrain, while carrying basic fighting and subsistence loads. Therefore the capability of assessing and predicting troop mobility over a variety of terrain while carrying loads is an important military concern for combat operations.

The energy costs of walking have been extensively investigated. It has been shown that load, speed, weight, terrain, and slope all have a direct effect on energy expenditure. These relationships are constant and predictable. Givoni and Goldman (2) have developed an equation for prediction of metabolic cost when all of the above factors are known:

$$M=\eta(W+L)(((2.3+0.32(V-2.5)))+((G(0.2+0.7)(V-2.5)))$$

M=metabolic rate, kcal/hr

η=terrain factor (η=1.0 for treadmill)

(W+L)=body weight plus external load, kg

V=walking speed, km/hr

G=slope (grade), %

This equation gives an energy cost prediction with a correlation of r=0.99. Engel and Goldman (1) found that the above equation is applicable to women as well.

Hughes and Goldman (3) found that men tend to adjust their individual pace to 425 kcal/hr + 10% when asked to walk at a maximum voluntary pace. For fit individuals this represents 40 to 50% of their $\dot{V}O_2$ max. Soule and Goldman (5) used this study to develop a prediction of time for a given terrain and load with the assumed maximum voluntary work level. Terrain coefficients were developed and used to predict completion time for both high and low fit males, and compared with a "select" group of Boston University crew team females. The estimated energy costs did not discriminate across the two fitness levels, and the women kept approximately the same speed and energy output as the men. Since the female subjects were all members of the winning Boston University crew team, their data may not be generalizable to the female population as a whole.

More recently, Pandolf, Givoni, and Goldman (4) have revised the predictive formula for determining metabolic rate for walking and load carrying. This newer formula was shown to be an excellent predictor at a much wider range of speeds and also allowed an adjustment for load as a function of body weight. The formula is as follows:

$$M=1.5W+2.0\,(W+L)\,(L/W)^2+\eta(W+L)\,((1.5V^2+0.35VG))$$

When

M=metabolic rate, watts

W=subject weight, kg

L=load carried, kg

V=speed of walking, m/sec

G=grade, %

η=terrain factor (η=1.0 for treadmill)

It seems reasonable to hypothesize that women or troop units of different physiological states and/or lower levels of physical fitness (i.e. $\dot{V}O_2$ max and body composition) would adopt different self pacing moderate to hard work levels and therefore have different mobility rates. The aim of the present study, therefore was to compare between male and female troop mobility in four different terrains. The data obtained will be used to further refine our energy cost prediction equation.

Progress:

The study has been completed. In the effort to compare voluntary hard work rate of men and women, 12 subjects (6 men and 6 women) walked over four different terrain at our Sudbury Annex field site, carrying two different loads (10 kg and 20 kg) and no load (Figure 1). The four terrain consisted of heavy brush (1.3 km), light brush (1.4 km), dirt road (1.8 km), and blacktop road (1.6 km). They were traversed consecutively during each trial.

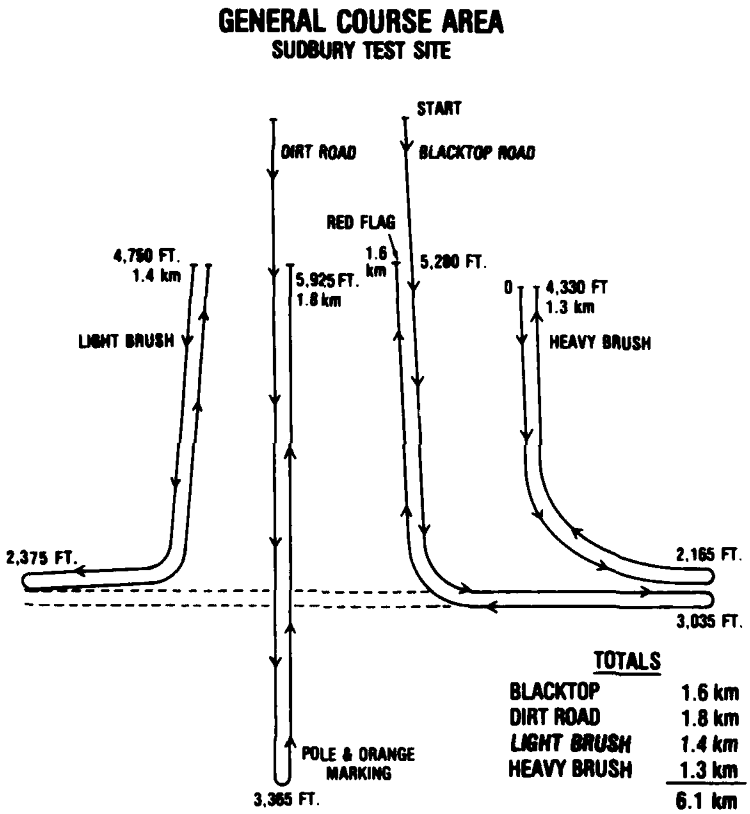

Figure 1. General Course Area Sudbury Test Site

Each subject was timed to determine speed on each course. Heart rates were also measured by palpation at the end of each course run. Speeds on the courses and previously determined terrain coefficients were used to determine

metabolic cost (kcal/hr). Maximal oxygen uptake ($\dot{V}O_2$) tests and lean body mass measurements were determined for all subjects prior to the field testing.

Metabolic cost of the males was found to be significantly and consistently higher than the females, on each course and with each load carried (Table 1). The mean metabolic cost for the males (475 kcal/hr) with no load on all four terrains was 51% greater than that for females (314 kcal/hr). Carrying 10 kg, the mean metabolic cost for the males was 439 kcal/hr, 39% greater than the 315 kcal/hr mean for the females. Carrying 20 kg, the cost for the males was an average 501 kcal/hr, 60% greater than the 313 kcal/hr mean for the females.

TABLE 1

Comparison between Males and Females of Self-Paced Speed, Metabolic Cost and Percent of Maximal Oxygen Uptake to Traverse Four Different Terrain

	0			10 kg			20 kg		
	Speed m/sec	Met.Cost kcal/hr	% VO_2max	Speed m/sec	Met.Cost kcal/hr	% VO_2max	Speed m/sec	Met.Cost kcal/hr	% VO_2max
Male									
HB	1.75	483	46	1.52	434	42	1.54	498	48
DR	2.03	449	43	1.76	398	39	1.81	468	45
BR	2.16	492	48	1.92	453	44	1.91	510	49
LB	1.97	477	46	1.82	470	46	1.83	529	51
Mean	1.98	475	45.8	1.75	439	42.8	1.77	501	48.3
Female									
HB	1.38	281	39	1.25	287	40	0.99	279	40
DR	1.76	301	42	1.63	309	43	1.48	312	44
BR	1.91	335	47	1.74	342	48	1.59	342	48
LB	1.78	337	48	1.56	323	45	1.40	320	45
Mean	1.71	314	44.0	1.55	315	44.0	1.37	313	44.3

HB, heavy brush; DR, dirt road; BR, blacktop road; LB, light brush

When expressed as percent of the subjects' maximal aerobic capacity ($\dot{V}O_2$ max), there were no differences found between the males and females as can be seen by referring to Table 1. The means for the males carrying no load, 10 kg, and 20 kg was 46, 43, and 48% $\dot{V}O_2$ max respectively, while the average for the females was 44% $\dot{V}O_2$ max for each load.

These data suggest that voluntary hard work rate depends upon aerobic capacity. The best predictor of speed on each terrain is 45% $\dot{V}O_2$ max. This also suggests that a value close to 45% $\dot{V}O_2$ max may be a better predictor of troop mobility than the maximum voluntary pace of 425 kcal/hr $\pm$ 10%. The men tended to adjust their individual pace much closer to 425 kcal/hr $\pm$ 10% than did the women, but both men and women worked at almost the same percent of their $\dot{V}O_2$ max or aerobic capacity throughout the study.

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2. Givoni, B. and R. F. Goldman. Predicting metabolic energy cost. J. Appl. Physiol. 429-433, 1971.

3. Hughes, A. L. and R. F. Goldman. Energy cost of "hard work". J. Appl. Physiol. 29:570-572, 1970.

4. Pandolf, K. B., B. G. Givoni and R. F. Goldman. Predicting energy expenditure with loads while standing or walking very slowly. J. Appl. Physiol. 43:577-581, 1977.

5. Soule, R. G. and R. F. Goldman. Terrain coefficients for energy cost prediction. J. Appl. Physiol. 9:73-80, 1955.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Hard Work for Walking on Snow of Various Depths
Investigators:	Kent B. Pandolf, Ph.D., Fred R. Winsmann and Ralph F. Goldman, Ph.D.

Background:

In a previous study, the metabolic energy expenditure and terrain coefficients for walking on snow were determined using 6 male volunteer subjects. These subjects each walked for 15 minutes at each of two fix-paced speeds, 0.67 and 1.12 m/s (1.5 and 2.5 mph), on a treadmill (level) and on a variety of snow depths. Energy expenditure increased linearly with increasing depth of footprint depression, reaching a ratio of about 5:1 when a 45 cm footprint depression was compared to 0 cm depression. Although these subjects were considered above average in terms of physical fitness (mean $\dot{V}O_2$ max = 51.4 ml/kg•min), all stopped walking because of exhaustion at an average footprint depth of 35.0 cm at a walking speed of 1.12 m/s. Practical limits for snow walking without snowshoes not exceeding about 50% $\dot{V}O_2$ max were developed, with 20 cm being the maximal depth at 0.67 m/s and 10 cm at 1.12 m/s (3).

Certainly, walking on snow is a very tiresome form of human locomotion (1,2,3). However, little is known about the self-paced work rates soldiers would adopt as "hard work" for prolonged durations of snow walking.

Progress:

This study was developed to provide information about (a) the measured steady-state energy expenditure for self-paced snow walking at various snow footprint depths and (b) the effect of load carrying (backpack) on self-pacing at various snow depths.

Six healthy male volunteers, each less than 30 years of age, from the

Institute staff will first have a determination of their maximal oxygen uptake performed on a treadmill in the laboratory. They will walk at 1.56 meters per second (3.5 mph) on a level treadmill; the grade will be increased by 2.5% every two minutes, heart rate will be determined from continuously recorded electrocardiogram. At and above a heart rate of 160 beats/min expired air samples will be obtained during the last minute of each grade elevation. A plateau in calculated oxygen uptake (sample differences of less than 150 ml/min or 2.1 ml/kg•min) increase will determine the maximum $\dot{V}O_2$ (analysis and calculation will be completed before each successive grade increment is instituted).

In the second part of the study, the subjects will each walk a mile outdoors in 3-5 different depths of snow (up to approximately 20 inches deep). Subjects will walk at a self-determined voluntarily "hard" pace which they are able to sustain for 2-4 hours under each of three load conditions: in field clothing, and combat boots, but without backpack, with a 10 kg backpack and with a 20 kg backpack. At each quarter mile, expired gas samples will be collected in a Max Planck gasometer for four minutes; these will be analyzed for oxygen and the results used to determine energy expenditure. Heart rate will be determined by radial pulse count, for 30 seconds after each quarter-mile walk. After each walk, the temperature, wind velocity, snow-water content, and the depth of footprint depression in the snow will be measured. Techniques and calculations will be as reported by Pandolf et al. (3).

Unfortunately, insufficient snowfall and cover in this area prevented our Division from conducting this study during the winter and early spring months of FY79. Hopefully, in FY80 it will be possible to go TDY to either Vermont or New Hampshire in order to conduct a field study to accomplish the research needs of this project, in addition to establishing and possibly using the snow course at USANARADCOM. These options seem mandatory considering the unpredictability of weather conditions and snow cover in this area.

Presentations:

1. Goldman, R. F., M. F. Haisman and K. B. Pandolf. Metabolic energy cost and terrain coefficients of walking on snow. Paper delivered at the Third International Symposium on Circumpolar Health, Yellowknife, Northwest Territory, (Cda) July 8-11, 1974.

2. Pandolf, K. B., F. R. Winsmann, M. F. Haisman and R. F. Goldman. Metabolic energy expenditure and terrain coefficients for walking on snow. The Physiologist 17:301, 1974.

Publications:

Pandolf, K. B., M. F. Haisman and R. F. Goldman. Metabolic energy expenditure and terrain coefficients for walking on snow. Ergonomics 19:683-690, 1976.

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Establishing Terrain Coefficients for Predicting the Energy Cost of Oversnow Movement Aided by Military Skis and Snowshoes

Investigators: Fred R. Winsmann and Gerald W. Newcomb

Background:

Previous studies in the Military Ergonomics Division have defined coefficients for predicting the energy cost of walking in combat boots at a fixed pace on specific terrain relative to the energy cost of walking on treadmills (1,2). Coefficients for 6 terrain (Blacktop Road, Dirt Road, Light Brush, Heavy Brush, Sand, Swamp) devoid of snow were first established in 1972 (4,5). More recently, coefficients for walking in snow have been defined as a function of the depth of footprint (2) to extend the energy cost of prediction equation for military foot movement reported in 1971 (1). To include oversnow movement in Arctic footwear, with skis and snowshoes terrain coefficients are needed for the energy cost of:

a. Fixed-pace snow walking in the current Army standard cold-dry vapor barrier boot.

b. Fixed-paced snowshoeing and cross-country skiing, utilizing current Army standard equipment.

We expected that the energy cost would be greater due to the added weight of the footwear and oversnow equipment (4), but the added cost cannot be predicted accurately because of differences in traction, penetration in the snow and snowloading of skis and snowshoes. Although the energy cost of oversnow movement on skis and snowshoes of civilians has been reported in the literature, these reports cannot serve as a data base for prediction because the subjects are generally very skillful, highly fit subjects of varying ages, most often using recreational or competitive equipment which is much lighter in weight than that provided the less experienced U. S. soldier.

Progress:

During the winter of 1977-78, energy cost data were collected from 10 subjects carrying 5.8 kg packloads, 6 subjects carrying 15.8 kg loads and 2 subjects carrying 25.8 kg loads as they snowshoed for 30 min on a packed trail. Speeds were 0.67, 0.89 and 1.34 $m \cdot s^{-1}$ (1.5, 2 and 3 mph); speeds below 1.5 mph were found too slow for the maintenance of proper balance. Depending on the individual, the weight of clothing, boots and snowshoes added from 6.7-10.1 kg to the total load.

Energy cost data is shown in Table 1 for the 6 subjects who carried 5.8 and 15.8 kg loads at the 3 speeds. Analysis of variance showed that speed affected the energy cost of snowshoeing significantly ($p < 0.01$), while increasing the pack weight 10 kg did not. Quite possibly, the 10 kg increment in pack weight added only a relatively small amount to the metabolic cost of transporting the total load of body, pack, clothing and foot gear. This possibility can be explored statistically when data from a larger sample of individuals is collected.

TABLE 1

Comparison of Measured (meas) and Predicted (pred) Energy Costs of Snowshoeing and Calculated Terrain Coefficients (η) as Related to Speed and Pack Weight, Means of 6 Subjects ± Standard Error

Speed ($m\ s^{-1}$)	Pack Weight (kg)	Energy Cost (W) meas	Energy Cost (W) pred	η
0.67	5.8	317 ± 23	175 ± 12	3.4 ± 0.2
	15.8	335 ± 19	196 ± 10	3.1 ± 0.2
0.89	5.8	418 ± 94	221 ± 15	2.9 ± 0.3
	15.8	418 ± 19	247 ± 13	2.5 ± 0.1
1.34	5.8	615 ± 39	351 ± 23	2.1 ± 0.1
	15.8	674 ± 36	392 ± 22	2.1 ± 0.1

The predicted energy cost of carrying the same total weight as a single load on a blacktop road (3) is also shown in the "pred" column in Table 1. Comparison of the measured and predicted values shows the energy cost of snowshoeing to range from 1.7 to 1.9 times that of road walking, irrespective of speed or pack weight. The overall average factor is 1.76, with a very small standard deviation of 0.08. If this preliminary estimate is confirmed by data from a larger sample carrying the same loads and for heavier loads, then snowshoeing on a level, packed trail is about 75% more difficult than carrying the same total load on a hard surface road.

In all the other terrain investigated, including snow walking (1,2,5), only the speed term needed correction by a terrain factor (symbolized by η) to adequately predict the energy cost. This is the first time that one overall multiplier for the entire energy cost equation was required in order to express the effect of terrain on energy cost. However, such a result is not unreasonable, as the present energy cost prediction equation (3) consists predominantly of terms for load bearing while standing and walking on the level each of which may be affected by a different aspect of snowshoeing on a level trail.

Just lifting the legs while on snowshoes with no forward motion while bearing the weight of the snowshoes, boots and extra cold weather clothing may well involve added muscular effort in order to maintain balance, particularly on slippery snow surfaces. This is shown by the difficulty in maintaining balance while walking on snowshoes at very slow speeds. It was obvious that subjects walked with the legs spread apart in order to prevent stepping on the inside edges of the snowshoes. This induced a side-to-side rocking motion which disturbed normal balance and quite reasonably could induce a large increment in the energy cost of just moving the feet in place. Forward motion also requires more energy when hobbled by cold weather clothing and with weight on the extremities (4). Back- or side-slip of the snowshoes also add another increment to the energy cost of forward motion on snowshoes.

In order to determine the multiplicative coefficient for the total energy cost equation, the sample of subjects walking at the 3 speeds and wearing the 3 pack loads should be enlarged to 8-10. In addition a separate study of the energy cost of breaking trail is required to assess the metabolic effects of different depths of unbroken snow, not addressed in the current study, but necessary for applying the energy cost prediction equation in the battlefield environment.

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 In-House Laboratory Independent Research

Work Unit: 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing, and Equipment

Study Title: Evaluation of Fitness Reference Standards of Body Composition

Investigators: Nancy A. Pimental, Richard L. Burse, Sc.D. and Ralph F. Goldman, Ph.D.

Background:

Current Army Regulations (AR 600-9) utilize height-weight tables as one measure of physical fitness of the soldier (1). Those individuals who do not meet these weight standards could receive unfavorable evaluation report forms or unfavorable remarks in their official military personnel file, or might not be permitted to re-enlist, or may even be discharged from the Army. While the use of such height-weight tables is often sufficient, for some individuals the use of weight alone as an indicator of fitness may be misleading. These individuals include those who have a very high muscle mass or those who are fit but who have large uniquely located fat deposits which are genetically determined. It might be unrealistic, indeed in some cases physically hazardous, to expect weight losses as indicated by AR 600-9 in these soldiers.

It is therefore desirable to use an alternative method to evaluate fitness and establish weight goals for the soldier. Such a method should give information as to the body composition of the subject in order to separate the above-described individuals from the merely overweight. This can be done easily and reliably by the use of skinfold assessment of total body fat content.

The purpose of this ongoing study is to measure initial amounts of body fat and monitor changes in body fat in those soldiers who do not meet current Army weight goals. Collected data is given to the Medical Officer for use in prescribing diet and/or exercise programs.

Progress:

During FY79 the Medical Officer at USANARADCOM referred 11 military personnel for skinfold assessment. Of these 11, 2 were females and 4 were being reassessed after having been on diet/exercise programs. Skinfold measurements were taken with Lange calipers at 4 sites: subscapular, triceps, biceps and suprailiac. The method of Durnin and Womersley was used to calculate % body fat (2). Heights were measured with an anthropometer and weights were measured with a balance scale. The data is presented in Table 1. Table 2 shows mean fat content, classified according to age and sex, from a study by Durnin and Womersley on 481 men and women (2).

TABLE 1

Anthropometric Measurements and Weight Limits

Subject	Visit	Sex	Age	Height	Weight	% fat	Lean Body Mass	(AR 600-9) Weight Limit	LBM plus Mean % fat
1	#1	M	27	73.1	238.5	28.1	171.4	208	182
2	#1	M	43	71.1	213.0	35.8	136.6	197	202
3	#2	F	31	66.7	157.0	33.4	104.7	151	156
4	#1	F	26	68.7	169.0	40.6	100.3	158	141
5	#2	M	28	73.4	231.0	25.8	171.4	211	202
6	#4	M	42	70.9	214.0	35.9	137.3	197	183
7	#1	M	30	68.9	216.2	30.4	150.5	186	195
8	#1	M	22	69.5	199.0	25.0	149.4	189	176
9	#1	M	38	64.0	189.8	28.0	136.6	160	177
10	#1	M	34	71.2	209.5	29.5	147.6	197	192
11	#2	M	32	70.7	242.0	31.7	165.2	195	215

TABLE 2

Mean Fat Content According to Age and Sex

Sex	Age	Mean % Fat
Male	17-19	15
	20-29	15
	30-39	23
	40-49	25
	50-72	28
Female	16-19	26
	20-29	29
	30-39	33
	40-49	35
	50-68	39

Using lean body mass plus mean % body fat as the criteria for weight standards, subject 3 would already have obtained her weight goal. Subjects 7, 9 and 11 would need to lose less weight than that required by AR 600-9. On the other hand subjects 2, 4, 5, 6 and 8 would be required to lose more weight than the current Army standards for their sex and height. In the case of subjects 1 and 10 the weight goals as determined by the height-weight table and by skinfold assessment are close.

Future work will include continuing to take initial skinfolds on referred military personnel and periodically measuring changes in body weight and body fat on these individuals. The results of this study, and recommendations for using skinfold assessment of body fat as a method of determining fitness of the soldier will be submitted to Military Medicine for publication.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Artificial Heat Acclimatization: Differences Between Cold and Warm Seasons
Investigators:	Yair Shapiro, M.D., Kent. B. Pandolf, Ph.D., Barbara A. Avellini, Ph.D., Nancy A. Pimental and Roger W. Hubbard, Ph.D.

Background:

Acclimatization is a physiological phenomenon that increases the heat tolerance of man by more effective and efficient heat dissipating mechanisms. Acclimatized men have a lower body temperature, lower heat storage, lower heart rate and somewhat higher sweat rate in comparison to a non-acclimatized man. A person is acclimatized to the heat and work load to which he is exposed. In nature, man becomes more and more acclimatized during the summer and less so during the winter. Artificial acclimatization is a well known procedure to acclimatize men to conditions in a particular experiment or before shifting them to work in hot areas (as is done with South African gold miners).

There are several methods for acclimatization which differ by the total duration and the daily length of exposure. The methods vary between 4 and 10 days of 90 to 240 min daily exposure. Very little is known about the relationship between the starting point of the acclimatization process and the final level that can be reached by artificial acclimatization.

The end point of acclimatization is conventionally said to occur when the common thermoregulatory parameters (sweat rate, body temperature, heart rate) reaches a definitive plateau. Is this plateau the same if we acclimatize men during the winter or the summer? In the former, man has a low level of natural acclimatization while in the latter he has a higher level of natural acclimatization. What are the relationships between artificial and natural acclimatization?

The purpose of this study is to define and compare the differences in artificial acclimatization when conducted in cold and hot seasons.

Progress:

Nine subjects participated in the first stage (warm season acclimatization) that had been completed. No significant changes between the first and tenth day of exposure to 104°F, 30% r.h. was found in the following parameters: rectal temperature, heart rate, sweat rate and plasma volume. This part of the study gives us the base line of natural acclimatization during the warm season. The second stage (cold season acclimatization) will be done during the winter of FY80.

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Prediction of Sweat Rate and Heat Tolerance

Investigators: Yair Shapiro, M.D., Leander A. Stroschein and Kent B. Pandolf, Ph.D.

Background:

Three major physiological factors determine the ability of soldiers to operate in hot climates: body temperature, cardiovascular adjustment and water balance. Models to predict body temperature and heart rate have been developed in this Institute; they have been validated for many combinations of environmental conditions, physical activity, clothing and external load carried by the soldier. These mathematical models predict the heart rate and rectal temperature at any given time and thus they predict tolerance limits; however, they did not predict water balance and its effects on tolerance. The metabolic heat production, clothing heat transfer characteristics, and the environment do predict the evaporative cooling required by the body (E_{req}) to maintain thermal balance. However, the maximal evaporation to the environment (E_{max}) is dictated by the vapor transfer properties of the clothing and the vapor pressure between the skin and the air. The absolute values of E_{req} and E_{max}, and the relation between them, dictate the thermoregulatory balance of the body and the associated water requirement (sweat) for this thermoregulation.

Progress:

Thirty-four acclimatized male, and nine acclimatized female soldiers (volunteers) participated in this study. They were divided into five groups and exposed two hours to: five climate combinations (air temperature 20-54°C, relative humidity (10-90%); with three metabolic levels (rest, 3 mph level walking, 3 mph 5% grade walking); and three clothing ensembles (shorts and

T-shirts, tropical fatigues, C.B.R. suits). The females wore only the shorts and T-shirts. Each two-hour test involved: 10' rest, 50' work, 10' rest, 50' work. Physiological measurements included heart rate, rectal temperature, mean skin temperature, energy expenditure and sweat loss. E_{max} and E_{req} were calculated from environmental conditions, metabolism, clothing insulation and permeability as follows: (1,2)

1. $E_{req} = M_{net} + E_{R+C}$ $\quad W/m^2$

where: $M_{net} = M - 0.098\ W_t \cdot V \cdot G / A_D$

M - metabolism (W/m^2), W_t - body weight (kg), V - walking speed (m/s),

G - walking grade (%), A_D - body surface area (m^2)

and $E_{R+C} = \frac{6.47}{clo*}(T_a - T_s)$ $\quad W/m^2$

(clo* - effective clothing insulation coefficient,

T_a - ambient temperature (°C), T_s - mean weighted skin temperature (°C))

2. $E_{max} = 14.2\ (\frac{im}{clo})* - (P_s - P_a)$ $\quad W/m^2$

where: $(\frac{im}{clo})*$ - effective permeability index

P_s - water pressure of the skin (mmHg)

P_a - water pressure of the air

The ratio of E_{req} to sweat rate was found to correlate well with E_{max} (Figure 1). Also, the correlation between predicted and measured sweat loss is high (Figure 2). The predictive equations for sweat rate were:

$$\text{males: Sweat rate} = 28 \cdot E_{req} \cdot (E_{max})^{-0.45};\ g \cdot m^{-2} \cdot h^{-1}$$

$$\text{females: Sweat rate} = 15 \cdot E_{req} \cdot (E_{max})^{-0.36};\ g \cdot m^{-2} \cdot h^{-1}$$

Since sweat rate equals water required, these equations can be used to predict the body's need for water replacement, and thus the logistics of water supply, under different combat conditions.

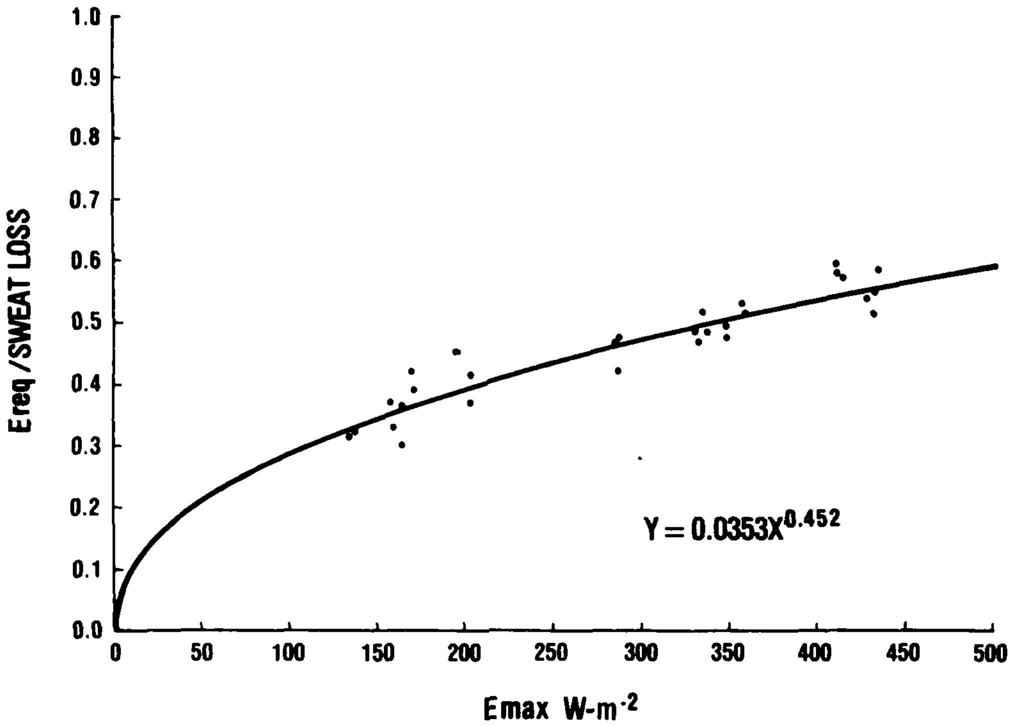

Figure 1. Correlation between E_{max} and E_{req}/sweat loss ratio (males).

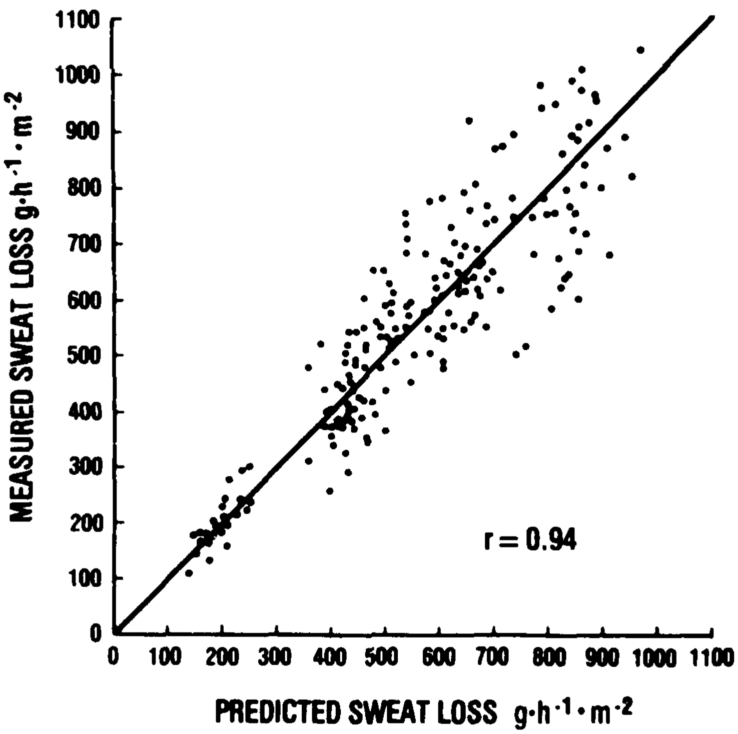

Figure 2. Correlation between predicted sweat loss and measured sweat loss (males).

Presentations:

Shapiro, Y., K. B. Pandolf, J. R. Breckenridge and R. F. Goldman. Predicting sweat rate from E_{req} and E_{max}. Fed. Proc. 38, Part II:1052, 1979.

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2. Givoni, B. and R. F. Goldman. Predicting heart rate response to work, environment and clothing. J. Appl. Physiol. 34:201-204, 1973.

Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Additive Effects of Solar and Metabolic Heat Load in Predicting Heat Intolerance

Investigators: Kent B. Pandolf, Ph.D., Yair Shapiro, M.D., Baruch Givoni, Ph.D., Fred R. Winsmann, John R. Breckenridge and Ralph F. Goldman, Ph.D.

Background:

The solar radiant environment as a function of the particular geographic region, hazy or clear sky, cloud cover, terrain cover and albedo, time of day and solar elevation is an important consideration for military operations in hot environments. This Division has developed methods of prediction for the actual solar heat load arriving at the skin in lightly clothed men (1) and more heavily clothed men (2). However, these studies have been of a theorectical physical nature, validated by direct measurement on heated, sweating copper manikins.

Although we have been able to develop the ability to predict rectal temperature and heart rate responses to work, environment and clothing (3,4), further refinement of our predictive capabilities are seen to be necessary. It was the purpose of this study to evaluate the decrement in tolerance time or performance to work or rest in the heat as effected by a simulated ambient solar heat load. The results of these experiments should provide adequate data for integrating the metabolic responses of solar and metabolic heat and enable us to predict more accurately the soldier's responses to operational combat clothing and equipment during actual field situations in hot environments.

We have completed the first in a series of experiments involving the effects of solar radiant environment on soldier's performance to work or rest in the heat. Initially, 24 subjects were acclimatized to heat walking in shorts at 1.34 m/s for two, 50-min periods separated by 10-min rest at 49°C, 20% R.H.. After six days of acclimatization, the 24 subjects were divided into three groups

of eight for experimental evaluations during either rest, walking at 1.34 m/s, or walking 1.34 m/s at a 5% grade. A bank of 72 infrared 350 watt lamps were secured at near ceiling height in the USANARADCOM tropical environmental chamber. This bank of lights simulated approximately 90% of a typical, severe solar heat load. Subjects were evaluated during rest or walking (1.34 m/s, 0 or 5% grade), at 40°C, 32% R.H. and 35°C, 75% R.H. with and without the solar radiant load while wearing either shorts, socks and sneakers or the combat tropical uniform. The proposed experimental duration was a total of two hours (10 min rest, 50 min work, 10 min rest, 50 min work). During these experiments water was administered ad libitum while air motion was constant at approximately 1 mph.

Progress:

An extensive statistical and quantitative analysis of these experimental findings concerning solar heat load (Q_s) has been completed which involved a variety of physiological measurements. These physiological measurements included heart rate (HR), rectal temperature (T_{re}), sweat rate ($\dot{m}_{sw}$) and energy expenditure (M). In nearly all statistical contrasts of final test values, Q_s resulted in higher ($P < 0.01$) physiological responses (range of mean values: HR, 14-42 b/min; T_{re}, 0.45 - 1.48°C; $\dot{m}_{sw}$, 218-314 g/m^2·hr) as compared to no Q_s during rest or work. At similar levels of WBGT (~33.5°C), responses to Q_s (40°C, 32% R.H.) were similar to no Q_s (49°C, 20% R.H.) dressed in shorts (walking, 1.34 m/s at 5% grade) and tropical uniform, (walking 1.34 m/s). While HR and M did not differ statistically with Q_s, the $\dot{m}_{sw}$ (both uniforms) and T_{re} (shorts only) were statistically higher ($P < 0.05$) with Q_s. These findings illustrate the importance of considering the solar heat load components in the heat balance equation for outdoor environments. The marked increase in rectal temperature with the simulated heat load in both clothing systems and environmental conditions during rest or work is quite apparent as illustrated in Figure 1. More recently, our Division has collaborated with a visiting scientist from Israel (Dr. Baruch Givoni) concerning the development of prediction equations relative to

rectal temperature and heart rate as influenced by solar heat load. A preliminary equation developed to predict the impact of solar heat load on rectal temperature is as follows:

$$T_{re(f)} = 36{:}75 + 0.004\ (M - W_{ex}) + 0.0011H(c) + 0.0025H_{(r)}$$

$$+0.8\ \exp\ (0.0047\ (E_{req} - E_{max}))$$

where: $E_{req} = H_c + H_r + (M - W_{ex})$

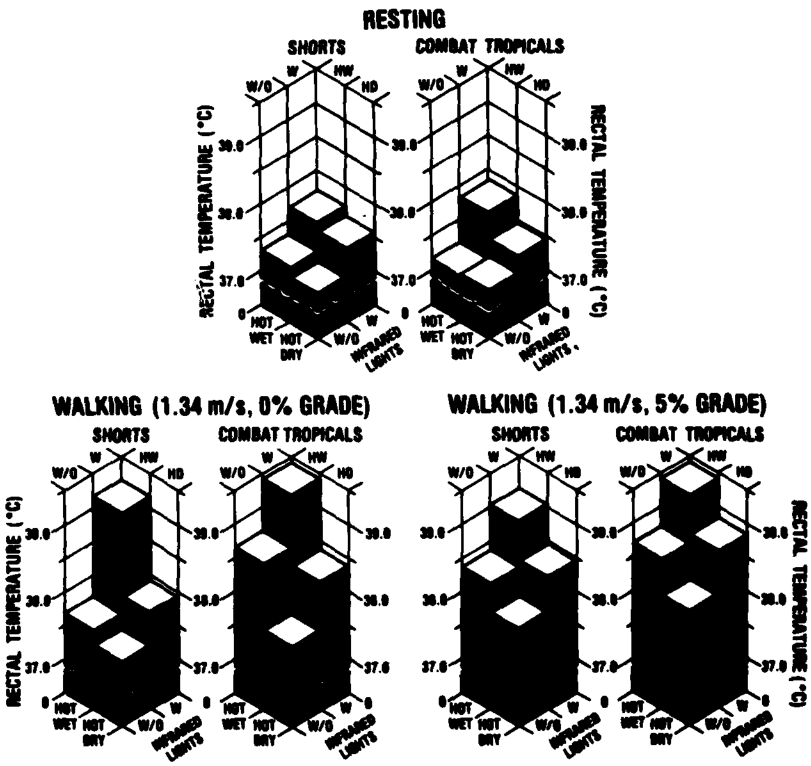

Figure 1. Rectal temperature responses for our subjects during rest and work wearing either shorts or combat tropical uniforms in hot/wet or hot/dry environments with (W) and without (W/O) simulated solar heat load (infrared lights).

As part of this same study, other individual blocks of experimentation will be conducted in the future. In these studies, physiological responses to simulated solar heat load, will be evaluated in the full Arctic ensembles in cold environments; CBR protective clothing and body armor ensembles will also be evaluated in hot environments. Additionally, a variety of radiant heat loads will be evaluated at different wind speeds and also various work/rest periods will be studied as affected by a simulated solar heat load.

Presentations:

Pandolf, K. B., Y. Shapiro, J. R. Breckenridge and R. F. Goldman. Effects of solar heat load on physical performance at rest work in the heat. Fed. Proc. 38:1052, 1979.

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Sex Differences in Heat Tolerance and Acclimatization

Investigators: Yair Shapiro, M.D., Barbara A. Avellini, Ph.D., Nancy A. Pimental and Kent B. Pandolf, Ph.D.

Background:

The reactions of men to changes in environmental temperature have served as the basis for our understanding of human heat tolerance and thermoregulation. There appears to be less certainty about the thermoregulatory patterns of women, however. Physiologial responses to heat stress may be expected to differ in men and women due to several possible factors, including the lower cardiorespiratory fitness (1), the higher body fat content (2), the lower body weight (3), the lower skin surface area and the higher surface area-to-mass ratio (A_D/wt) (4) of women compared to men. In addition, the fluctuating hormonal levels of estrogen and progesterone accompanying the menstrual cycle may also influence women's tolerance to heat stress.

Several studies have shown that women thermoregulate less effectively than men when exposed to an acute heat stress (5). Under the same heat load, core temperature and heart rates were higher (6) and sweat rates were substantially lower (6) in women. However, when the cardiorespiratory fitness of the men and women was considered, physically fit women were found to have similar (1) or even lower core temperatures and heart rates than fit men during an acute heat exposure despite their lower rates of sweating. Although heat acclimatization served to eliminate many of the sex-related physiological differences, sweat rates still remained lower for women (6).

One of the sources for the controversy in the literature regarding apparent sex-related thermoregulatory differences may result from the environmental conditions under which the experiment was conducted.

The purpose of this study was to define the possible physiological differences between the sexes for humid and dry heat and to suggest the thermoregulatory mechanisms involved.

Progress:

Nine female and 10 male preacclimatized volunteer soldiers served as subjects. The subjects were exposed to a comfortable climate (20^{o}C, 40% rh), mild-wet weather (32^{o}C, 80% rh), two hot-wet conditions (35^{o}C, 90% rh; 37^{o}C, 80% rh) and two hot-dry conditions (49^{o}C, 20% rh; 54^{o}C, 10% rh). Exposures lasted 120 min: 10' rest, 50' walk (1.34 $m \cdot s^{-1}$), 10' rest, 50' walk. During hot-dry exposures, heart rate (HR) and rectal temperature (T_{re}) were significantly lower for males than females by 13 and 20 beats$\cdot$min^{-1} and by 0.25 and 0.32^{o}C for the two conditions (Figure 1); no significant differences in sweat loss ($\dot{m}_{sw}$) were observed. During hot-wet exposures, both mean final T_{re} and $\dot{m}_{sw}$ were lower in females than males by 0.34 and 0.24^{o}C and by 106 and 159 $g \cdot m^{-2} \cdot h^{-1}$, respectively (Figure 2) (males sweated 25 and 40% more than females). None of these differences correlated with maximal oxygen uptake, body weight, skin surface area or percentage of body fat. During hot-wet exposures, a negative relationship between surface area-to-mass ratio (A_D/wt) and T_{re}-mean skin temperature, HR and change in heat storage was found (Table 1). It was suggested that three major factors are involved in these differences: (a) higher A_D/wt for females than for males, (b) better sweat suppression from skin wettedness for women and (c) higher thermoregulatory set point for women than for men.

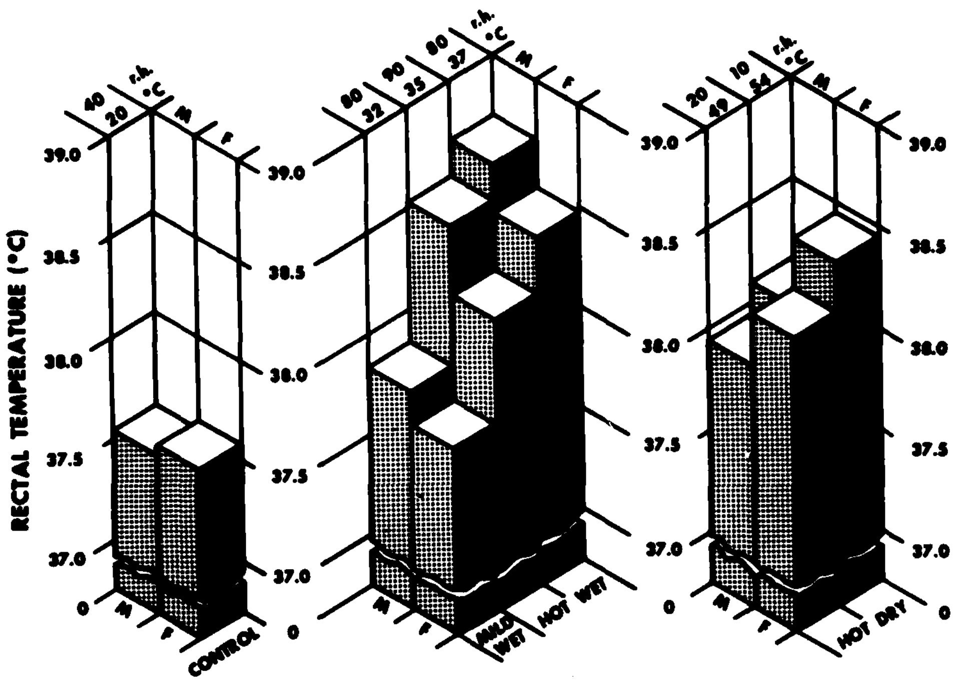

Figure 1. Comparison of mean final rectal temperature (T_{re}) between males (M) and females (F) in a control-comfortable climate (20°C, 40% rh), humid climates (32°C, 80% rh; 35°C, 90% rh; 37°C, 80% rh) and dry climates (49°C, 20% rh; 54°C, 10% rh).

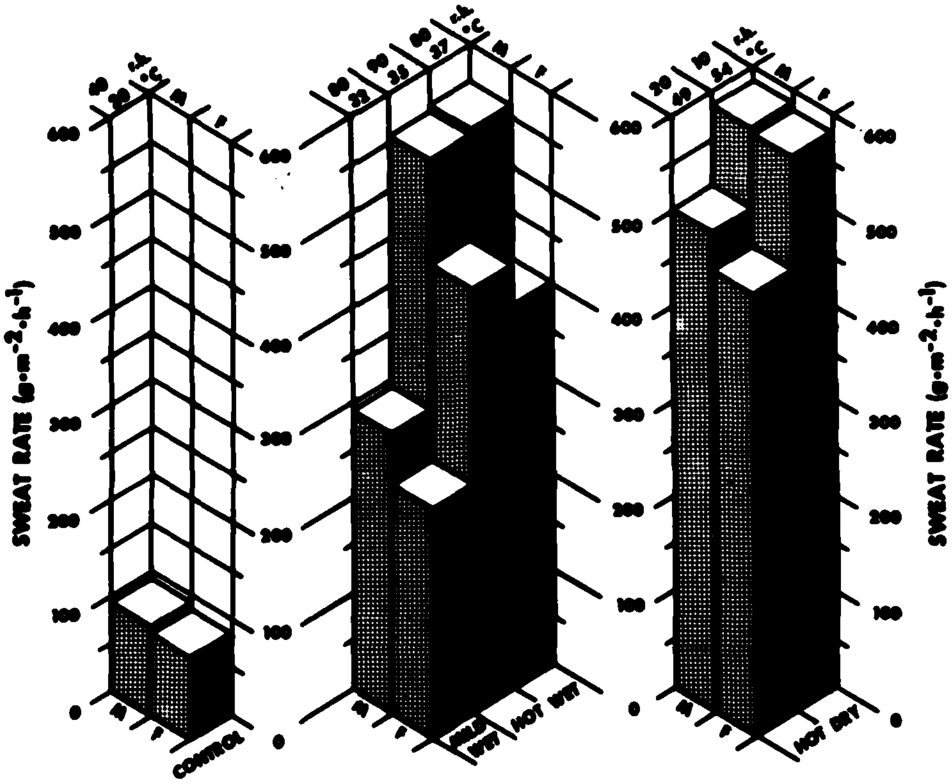

Figure 2. Comparison of mean hourly sweat rate ($\dot{m}_{sw}$-g•m^{-2}•hr^{-1}) between males (M) and females (F) in the comfortable climate, the three humid climates and the two dry climates.

TABLE 1 Surface area-to-mass ratio (A_D/wt) and thermoregulation

		FEMALES		MALES	
		Higher A_D/wt	Lower A_D/wt	Higher A_D/wt	Lower A_D/wt
	No. of Subjects	4	5	5	5
A_D/wt	($cm^2 \cdot kg^{-1}$)	297 ± 5*	272 ± 6	273 ± 5	244 ± 7
	T_{re}, °C	38.10 ± 0.11	38.27 ± 0.08	37.85 ± 0.11	38.02 ± 0.12
HOT-DRY	$\bar{T}_{sk}$, °C	36.30 ± 0.30	36.18 ± 0.50	35.96 ± 0.09	35.64 ± 0.39
	ΔS, $W \cdot kg^{-1}$(1st h)	0.486 ± 0.076	0.635 ± 0.089	0.589 ± 0.055	0.531 ± 0.100
49°C, 20%	HR, $beats \cdot min^{-1}$	131 ± 9.7	130 ± 4.2	116 ± 5.5	118 ± 4.6
	$\dot{M}_{sw}$, $g \cdot kg^{-1} \cdot h^{-1}$	13.83 ± 0.76	12.47 ± 0.57	13.38 ± 0.77	12.59 ± 0.91
	T_{re}, °C	38.35 ± 0.05	38.60 ± 0.09	38.62 ± 0.13	38.84 ± 0.11
HOT-WET	$\bar{T}_{sk}$, °C	36.15 ± 0.17	36.44 ± 0.15	36.40 ± 0.10	36.62 ± 0.11
	ΔS, $W \cdot kg^{-1}$(1st h)	0.686 ± 0.022	0.804 ± 0.081	0.834 ± 0.115	1.065 ± 0.046
37°C, 80%	HR, $beats \cdot min^{-1}$	140 ± 4.1	145 ± 4.3	147 ± 7.8	151 ± 1.5
	$\dot{M}_{sw}$, $g \cdot kg^{-1} \cdot h^{-1}$	11.49 ± 1.79	11.19 ± 0.91	14.61 ± 1.04	14.30 ± 0.91

*Mean ± S E

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 053 Prediction of Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Role of Dehydration in Limiting Human Performance While Working in the Heat

Investigators: Kent B. Pandolf, Ph.D., Baruch Givoni, Ph.D. and R. F. Goldman, Ph.D.

Background:

Approximately two years ago an investigation was conducted to study the acute phase of dehydration which is more characteristic of a military operation in hot environments. Predictive modeling of the effects of dehydration for important physiological performance parameters, such as rectal temperature (T_{re}) and heart rate (HR), was, to our knowledge, non-existent. Thus, the purpose of this investigation was to derive predictive formulas for rectal temperature and heart rate considering human performance of exercise in the heat.

Progress:

The technique for induction of dehydration was to define a characteristic morning weight for each of the 16 subjects by weighing over a period of four or five days before the start of the study. This established a "baseline" weight for each individual subject. Subjects were then brought into the laboratory and acclimated by walking in the heat at 1.34 m/s for two, 50-min periods separated by a 10 min rest at 49°C, 20% R.H. State of hydration was altered by having the subjects report to the Climatic Chamber at 2200 hrs each evening and "rest" at 49°C, 20% R.H. while withholding, allowing or encouraging water intake until the desired target dehydration was approached. At approximately 0300 hrs each morning, subjects were weighed and transferred to a comfortable room to sleep. At 0700 hrs all men were weighed, state of dehydration estimated, and given a

light standard breakfast with fluid adjustment appropriate to the target dehydration individually attempted.

Target hydration levels of 0, -3 and -5% of baseline were evaluated during rest or walking at 1.34 m/s, 0 and 5% grade, at 54°C, 10% R.H.: 49°C, 20% R.H.; 35°C at 24, 48 and 72% R.H. and 25°C, 84% R.H. Exposure time totaled 110 min while exercise involved two, 50-min walking periods with a 10 min intervening rest. Rectal temperature and mean weighted skin temperature were recorded continuously and HR checked periodically. The individual level of dehydration was maintained throughout the exposure by administration of water in amounts determined from the acclimatization days as adequate to maintain body hydration at the initial level. Subjects were studied only two days per week, allowing 48 hrs between exposures for full recovery of hydration and restful sleep. Thus, we evaluated three levels of metabolic rate, a wider variety of air temperatures and levels of humidity at three levels of hydration.

From the analysis of the experimental data described above, it was possible to express the effect of dehydration as proportional to the final elevation in the rectal temperature of hydrated individuals exposed to similar environments and work levels. The effects of the level of dehydration on rectal temperature are a faster rate of elevation and, therefore, a higher final level where the duration of exposure was limited; however, the final equilibrium temperature, if established, appears to be no higher than without dehydration at these levels. Formulas previously published for predicting rectal temperature (1) were modified using an exponent containing both a dimensionless constant and the level of dehydration in percent. Previously published predictive formulas for HR (2) were also modified to include a dimensionless constant which considered percent dehydration.

During rest, dehydration was found not to alter T_{re}. Predictive formulas (modified from J. Appl. Physiol. 32:812, 1972) at any time (t) and final T_{re} (T_{ref}) and the time pattern of change during work (T_{rew}) and recovery (T_{rer}) are:

$$T_{ref} = 36.75+0.004(M-W_{ex})+[(0.0128\ clo^{-1})(T_a-36)+0.8e^{0.0047}(E_{req}-E_{max})]e0.01D$$

$$\text{Work:}\quad T_{ref} = T_{reo} + (T_{ref} - T_{reo})\,[1 - e^{-k}(t - t_d)(1 + 0.1D)]$$

$$\text{Rec:}\quad T_{ret} = T_{rew} - (T_{rew} - T_{rer})[1 - e^{-00}(t - t_{drec})\, e^{-0.07D}]$$

where: D = % dehydration; op cit for other terms. A preliminary formula, which predicts heart rate considering dehydration is:

$$I_{HR}\ (\text{Dehyd}) = 25 + (\text{IHR} - 25)\ (1 + 0.06D)$$

Using this I_{HR} for dehydration, final HR, and HR at time t, are computed as previously published (J. Appl. Physiol. 34:201, 1973).

This predictive capacity to consider state of hydration has been tentatively added to our model which predicts military performance capacity and the occurrence of heat stress and/or heat casualties during military operations.

The tentative coefficients developed from these experiments resulted in only a minor adjustment to the original predictive formulas. However, these coefficients were derived from only one group of test subjects and somewhat limited work and environmental conditions. An entirely different group of test subjects need to be evaluated to validate the coefficients derived from previous dehydration experiments. The validation study will involve 8-16 acclimatized subjects, three levels of dehydration (0,3,5%), two levels of physical work (300 and 500 watt) and two environmental conditions (35^{o}, 45^{o}C).

While no additional data was collected during FY79, Dr. Baruch Givoni (visiting scientist, Ben Gurion University of the Negev, Israel) has suggested further refinements concerning the coefficients for prediction equations pertaining to state of hydration and also some further potential validating studies. However, the number of visiting scientists in our Division (Dr. William Evans, Boston University; Professor Gin Gee, Corning Community College; and Dr. Yair Shapiro, IDF), and the support necessary to sponsor their research during this fiscal year, postponed the starting data for these validating experiments. Hopefully, these validation studies will be conducted during FY80.

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment

Study Title: Comparative Methods of Auxiliary Cooling in Man

Investigators: Yair Shapiro, M.D., Kent B. Pandolf, Ph.D. and Ralph F. Goldman, Ph.D.

Background:

Auxiliary cooling is a very interesting and important field. Theoretically, it is much cheaper to cool the man than cool the whole environment; less energy is needed to cool a man by cooling his microclimate than by cooling the macroclimate. As an auxiliary cooling method, it has been proven that it is much more effective to use water suits or ice suits than to use a cool air suit. The main problem remaining unsolved is the control of the cooling rate. The most advanced control system was developed by Webb and colleagues (Webb Associates) (1). His system receives inputs from the subject's oxygen consumption and skin temperature and the resultant output is the water temperature of the suit. This control mechanism is very expensive and complicated and not applicable for general use. In Japan and in the gold mines of South Africa they use ice suits (dry ice in Japan and water ice in S.A.). It appears that these suits and especially the water ice variety, are very effective during high work loads in very hot environments. However, the direct contact of the cold surface with the skin is unpleasant and may induce local cold injury (especially with dry ice suits). Under milder conditions they can even overcool a man. To protect the user against these hazards, an insulated layer is used between the suit and the skin. Obviously, this layer of insulation reduces the efficiency of the suit.

We suggest that if the ice in the suit is replaced by materials which melt at a temperature closer to the skin temperature, the skin itself will be the regulator and control mechanism of the cooling rate.

Exposure to cold produces peripheral vasoconstriction and a decreased skin temperature. Thus, the temperature gradient from skin to suit decreases and

becomes closer to zero. When the body accumulates heat the peripheral blood vessels vasodilate and the skin becomes warmer. Thus, the gradient skin to suit becomes higher and the heat transferred between the body and the suit will be greater. In such a suit the physiological control mechanism of man will regulate the rate of heat transfer without any risk of cold injury. Such a suit can be called a "demand auxiliary cooling suit." Potentially, there are two problems with this concept: (a) the material substituted for ice has to be nontoxic and (b) it has to have a high latent heat of fusion, as close as possible to that of water. We know of two nontoxic materials: (a) $CaCl_2 \cdot 6H_2O$ and (b) acetic acid; the first one melts at 24.4°C and the second at 16.6°C, but the latent heat of both of them is 50-55% of water. Thus, the total "cold content" of such suits will be about half of that of water, or for the same effect the suit would have to be twice as heavy. The problem can be solved by developing a two layer cooling suit; the inner layer - high melting point - thin and close to the skin, and the other - one of ice - thicker than the inner one. The aim of this study is to develop an effective and safe auxiliary cooling suit for man.

Progress:

This study is in the stage of collecting the different suits from various places.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Collaboration and Prediction Modeling in Clinical Evaluations of Hyperthermia ($T_{re} \simeq 42^oC$) at the National Cancer Institute
Investigators:	Kent B. Pandolf, Ph.D., Gaither D. Bynum, M.D., Joan Bull, M.D., Leander A. Stroschein and Ralph F. Goldman, Ph.D.

Background:

The concept of critical thermal maximum (CTM) has been defined in the literature as the minimum high deep body temperature which is lethal to an animal (2). In man the CTM has been estimated at 41.6^oC - 42.0^oC (4). However, we previously reported data for sedated unacclimatized, well-hydrated men (cancer patients) heated one hour until esophageal temperatures of 41.6^oC – 42^oC, without sequelae, except for modest elevation of serum enzymes in 2 of 5 patients (1). These data, when combined with other observations in the literature (3), suggest that CTM be redefined as the particular combination of exposure time at elevated body temperatures which results in either subclinical (CTM_s) or clinical (CTM_c) injuries.

The second major concept in our report involved the presentation of a mathematical technique equivalent time at 42^oC (T_{eq} 42^o), for expressing hyperthermia in terms of body temperature and exposure time. The regression equation for these mathematical functions is of the form, $T = ae^{-bt}$ where "a" and "b" are constants and T is the temperature in ^oC. Time - temperature exposure data may then be normalized into equivalent times at 42^oC, by use of a modified regression equation. This equation is determined by solving the original equation for "a" using the approximate average rate constant "b" (b = 1.353) from our data, along with a time increment equal to 1 and a temperature T of 42^oC. The value for "a" obtained in this manner is equal to 4.7178×10^{24}. Temperature records may then be normalized to equivalent times at 42^oC by the summation of the following expression:

$$42^oC \text{ equivalent time } [(\Sigma \Delta \text{ Time}/4.7178 \times 10^{24})e^{-1.353T}]$$

The hyperthermia experienced by three of our subjects at three different rates of temperature rise and maximum T_{es} is expressed as equivalent time at 42°C (T_{eq} 42°), and presented in Figure 1. Although the time - temperature interaction of these individuals is markedly different, the exposure time can be easily compared when expressed as T_{eq} 42°C. A similar, or perhaps the identical, relationship may be usefully applied to studies of heatstroke mortality.

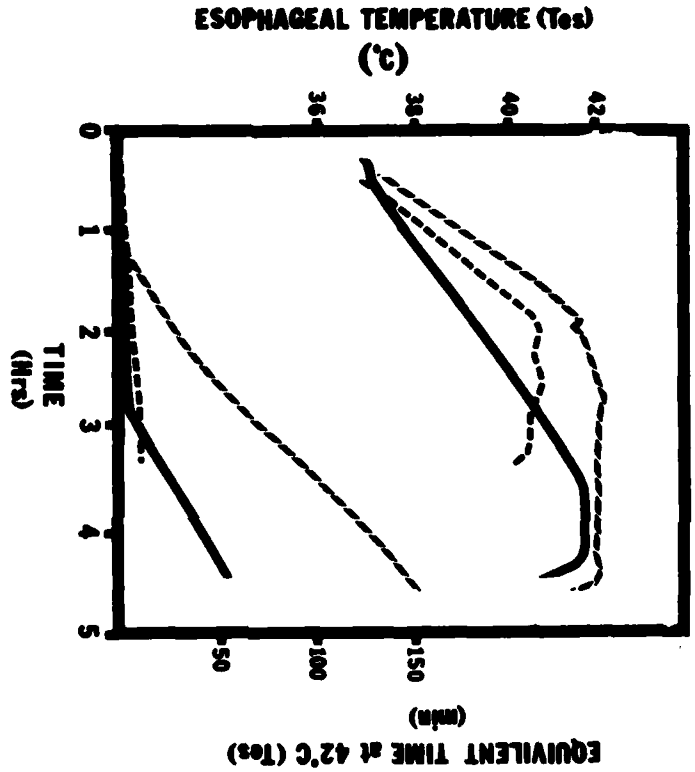

Figure 1. Esophageal temperatures (T_{es}) of three male patients (National Cancer Institute) to induced hyperthermia are plotted as a function of time. The corresponding calculated equivalent time required to achieve the same thermal injury at a T_{es} of 42°C (T_{eq} 42°) is plotted as a function of actual exposure time. The equation relating T_{eq} 42° as a function of actual exposure time and T_{es} is:

$$T_{eq}\ 42^{o} = (\ \Delta\ \text{Time}/4.7178 \times 10^{24})e^{-1.353}T_{es}.$$

Progress:

Currently, over 30 cancer patients have been evaluated during hyperthermic exposures at the National Cancer Institute (NCI). Multiple hyperthermic exposures (6 or more exposures) have been conducted on little more than half of this group of patients. The goal of our Division is to retrieve the cardiovascular and thermal response data of these patients and to analyze and organize these findings. However, a sufficiently large cohort must be evaluated in terms of multiple hyperthermic exposures in order to effectively model these responses. Hopefully, the cohort evaluated at NCI will grow sufficiently during FY80 to make data acquisition worth while. The last phase in the completion of this study will involve the prediction modeling of hyperthermia which is contingent upon the results from these volunteer patients. Both the acute physiological changes associated with induced hyperthermia and the acclimatization responses with repeated exposures are valuable for modeling purposes. Unfortunately, the mortality rate associated with these volunteer cancer patients has resulted in a lengthy time period in order to achieve the latter objective (acclimatization responses). Nevertheless, these observations will serve as a data base for physiological responses associated with passive hyperthermia and will be most constructive in assessing factors which contribute to heat exhaustion collapse. While no new data collection will be initiated at USARIEM, collaborative contact at NCI on this project will be continued.

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing, and Equipment

Study Title: Safe Exposure Times for Partial Immersion in Cold Water

Investigators: Gin K. Gee, Richard L. Burse, Sc.D. and Leander A. Stroschein

Background:

Previous studies at this Institute have investigated changes in heat production and body core and skin temperatures of resting men exposed to cold air (nude) or immersed in cold water (nude and immersion suited), some with body temperatures previously elevated by exercise (1-4). However, to date there have been no studies of exercising men partially immersed in cold water, or with fully wetted clothing, which could provide data concerning safe exposure times for foot soldiers moving in swamps or across streams. Such information is required for the safe conduct of field training exercises under cool, but non-freezing conditions and for the prediction of tolerance limits under combat conditions. The actual or extrapolated times at which rectal temperature (T_{re}) drops below 35°C or violent shivering incapacitates an individual serve as the criteria of impending hypothermia and represent a lower limit from which individuals can be safely rewarmed (5).

A pilot study has been completed in which 3 male volunteers were immersed in water to the waist and chest levels. Water temperatures (T_{H_2O}) were 10, 7.5 and 5°C controlled to ± 1.0°C by refrigerated coils along the wall of a cylindrical tank in which the subjects stood. Clothing was the standard fatigue uniform, steel helmet assembly and a 25-pound weighted vest to simulate the combat load. Air temperature was maintained equal to water temperature.

To simulate a movement and pause activity, subjects stood quietly for 10 min immediately after immersion and then performed repeated cycles of physical work for 20 min followed by 10 min quiet standing. These work-rest

cycles were repeated until the tolerance time was reached or two hours had elapsed. Work rate was held constant by requiring the subjects to step on and off a 43 cm high platform at a fixed rate. The measured energy expenditure while working ranged from 415 to 700 W, depending on the weight and buoyancy, and represents levels of moderate to moderately hard work. The 10°C immersions to either the waist or chest level did not cause core temperature to fall below 36°C, even after 2 hours. Although uncomfortable, the subjects withstood the exposures well. Heart rates were quite low for the severity of the work level presumably because of an augmented venous return induced by the profound vasoconstriction. Only one subject withdrew before 120 min exposure time, and that at 73 min for a severe headache. His T_{re} was 36.9°C and showed an essentially flat trend similar to those who withstood the full exposure. There was no suggestion in any of these exposures that T_{re} would have fallen to 35°C even had the exposures been lengthened to four hours.

The exposures at 5°C to waist level were another matter entirely. Neither of the two subjects was able to withstand even one hour exposure. The leanest subject suffered a rapid decline of core temperature to 35°C in about 20 min. The largest and fattest subject maintained his body temperature well, but was unable to lift his body weight with his legs after a little more than one-half hour. The presumed cause was cold-induced anaesthesia of the motor nerves serving the leg musculature, which could well have resulted in his drowning in a field situation. From the rapid onset of these two potentially fatal disabilities, it is readily apparent that 5°C water represents a thermal environment unsuitable for even brief military training operations. The onset of neuromuscular block or hypothermic core temperature conditions give no warning; indeed, the numbing effect of the cold water after immersion may give a false sense of security.

Immersion to the chest in 7.5°C water resulted in one subject suffering from a cramp in his left gastrocnemius muscle after 101 min. Since he was the same subject who suffered weakness of the leg musculature in 5°C water, the cause may have been the same. Body core temperatures were well maintained by both subjects for 1-1/2 to 2 hours; the leanest subject was not available for test. Since body fatness affects body cooling, especially when exercising (6), the impact on lean individuals cannot be predicted. However, since one disability did occur at 7.5°C with potentially serious consequences in the field, this water temperature also appears unsuitable for military training operations.

Progress:

The results of the above pilot study served as the basis for planning a more extended investigation into the effects of knee, waist and chest immersion in 5, 7.5^{o} and 10^{o} water and exposure in wet clothing. Ten subjects differing in percent body fat were evaluated at 5^{o}C (knee), 7.5^{o}C (knee, waist, chest) and 10^{o}C (knee, waist, and neck). Three of these individuals were between 20-28% body fat, four subjects between 15-18% body fat and three subjects between 8-11% body fat. As expected, it would appear that lean individuals are much more susceptible to injury from cold water immersion as compared to fatter individuals. Even for the least severe conditions evaluated (knee depth immersion, 10^{o}C) none of the lean individuals (8-11% body fat) could complete the projected 110 min exposure. These individuals showed a marked reduction in core temperature. Thus, safe exposure times for partial immersion in cold water will have to be made considering the sub-cutaneous fat content of the individual in addition to the water temperature and water depth. Further, the minimal water temperature which could be sustained for prolonged durations by lean individuals still has not been determined.

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Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Predictive Modeling of Man Undergoing Whole Body Immersion Cooling With and Without Protective Clothing
Investigators:	Hylar L. Friedman, M.D., CPT, Louis H. Strong, Ph.D. and Ralph F. Goldman, Ph.D.

Background:

This Institute has long been involved in the evaluation of clothing for its insulative properties in air and while immersed in water. In the past, various types of wet suits have been evaluated by copper manikin studies; insulation values for 1/4" vinyl, 3/8" polyurethene, and 1/4" neoprene suits have been found to be 0.43 clo, 0.61 clo, and 0.76 clo, respectively. Several studies have been carried out on nude men totally immersed in water at temperatures ranging from 20°C to 35°C, and other studies were performed in 20°C to 28°C water, both on nude men and men wearing the aforementioned wet suits. Data collected in these studies included changes in rectal and mean weighted skin temperature with time, and in some studies, metabolic rates and heat flow measurements.

A second model for predicting whole body rewarming in air after prolonged immersion is also being developed.

Progress:

Two models have been developed for the prediction of mean weighted skin temperature during cold water immersion. Factors considered include body mass, body fat, and height, peripheral insulation and central conductance, and initial skin and rectal temperatures.

The mathematical form of Model I is:

$$T_{s\,(t)} = Ae^{-bt} + Ce^{-dt} + Tw$$

where $T_{s\,(t)}$ = skin temperature as a function of time

T_w = water temperature in degrees Kelvin

A, C, b, and d are constants individualized for each subject and condition.

By utilizing the T_s (60 minutes), the end point of each experiment, it was possible to construct a formula to predict the difference between $T_{s\,(t)}$ and T_w at 60 minutes. Through many arduous calculations, values for b and d were optimized in terms of the parameters outlined above. A and C then were fixed by solving the boundary conditions of the experiment, with initial skin temperature $T_{s\,(o)}$, and T_w, and the equation for 60 minutes

(1) $T_{s\,(o)} = A + C + T_w$

(2) $T_s\,(60) = Ae^{-60b} + Ce^{-60d} + Tw.$

Model II is similar to the concentric shell model of Stolwijk (1) and considers the heat transfer through N contiguous compartments (N arbitrarily large) including the body core, a fat layer, a skin layer and thermal protective layers. The net energy density stored in the ith compartment is given by the heat transport equation to be

$$P_i\, C_{vi} \frac{dti}{dt} = \frac{xxx}{j \neq i}\; a_{ij}\,(T_i - T_j) + Qi\,(t)$$

where we have ignored the energy flux through the thermal gradient within each compartment. P_i and C_{vi} are respectively the mass density and specific heats of the ith compartment. The a_{ij} are heat transfer coefficients which describe the heat flux from compartment i to compartment j. Their reciprocals are the thermal resistances. The Q_i represent active sources or sinks of thermal energy operative in this compartment and may include metabolic heat production, an externally applied heating source, or heat directly applied to the skin through the cutaneous blood supply.

The general solution to the system of N coupled differential equations has been obtained in closed form for N temperature profiles T_i subject to an

arbitrary set of boundary conditions. The system has also been solved in reverse for $Q_i(t)$ in terms of an arbitrary temperature profile T_i.

A computer program was used to simulate the time development of mean weighted skin and rectal temperatures of six nude, male subjects having body fats ranging from 10 to 25%, and immersed in water at 20 and 28°C. The heat transfer coefficients from core to fat, and from fat to skin were determined by successful simulations of the time variations of experimental temperatures using the measured metabolic rates. These heat transfer coefficients, which differed from subject to subject by as much as a factor of 2.5, were found to be inversely proportional to the compartment surface area. These coefficients were successfully used to predict skin and rectal temperatures for the same set of subjects in protective clothing.

Currently two manuscripts are in preparation which will define the two different models (Model I and Model II) concerning the prediction of mean weighted skin temperature during cold water immersion described above. Further validation for both models may be necessary. For Model I improvements in the validity at water temperatures below 20°C will improve it's predictability. For Model II a wider distribution of % body fat will improve its applicability.

Presentations:

Goldman, R. F., H. Friedman, G. Gee, G. Bynum, J. Bogart, C. Levell and L. H. Strong. Metabolic versus vaso-constrictive response to cold water immersion. The Physiologist 22:46, 1979.

LITERATURE CITED

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Program Element:	6.27.77A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	053 Prediction of the Biological Limits of Military Performance as a Function of Environment, Clothing and Equipment
Study Title:	Operational Capability of Individually Carried Bureau of Mines Rescue Breathing Apparatus in Sub-Freezing Temperatures
Investigators:	Richard L. Burse, Sc.D., Lewis H. Strong, Ph.D. and Leander A. Stroschein

Background:

The US Army Research Institute of Environmental Medicine was requested by the Bureau of Mines (BuMines) of the U.S. Department of the Interior to determine the cold-weather capability of their rescue breathing apparatus (RBA). BuMines needed to know the lowest ambient air temperature between 0 and -30°C at which each of the three different models of currently certified RBA could be used by humans at rest and while performing light to moderate work (oxygen consumptions ranging from 0.3 to 2.0 liters/min). The RBA are of closed-circuit design, which means that the breathing gas mixture continuously recirculates. The CO_2 produced by metabolism is removed by a chemical scrubber and the O_2 consumed by the user is replaced from a small rechargeable gas cylinder. The CO_2 scrubber, oxygen bottle, gas expansion chamber and metering devices are all mounted on a frame which is worn like a back pack. The inspired breathing gas is supplied to the user by a hose connected to a full-face mask with a single large lens to provide vision and is returned to the back pack by another hose. Since the exhaled breathing gas contains moisture which is not removed during the recirculation process, the RBA are susceptible to freezing at temperature below 0°C. The three RBAs tested were all certified for use in U.S. mining operations at temperatures down to 0°C, but none had been previously tested by humans at lower temperatures. Although designed primarily to develop information of use to the BuMines, this study benefited the Army in two ways. First, the closed circuit RBA now certified by BuMines for

rescue work in mines are the same devices available for procurement by the U.S. Armed Forces; these devices require testing to determine their operational capability for use in military operations in cold weather. Second, members of this Institute gained knowledge of the procedure, techniques and instrumentation needed for cold weather testing of closed-circuit breathing devices and also of the parameters of RBA function which determine adequate performance under cold weather conditions. The latter knowledge is directly applicable to design guidance for military breathing devices for use under a variety of environmental conditions.

Progress:

Two samples of each of the three different RBA currently certified by BuMines were obtained for test. Two of these, the Scott and Drager-National, have nominal operation times of 4 hours and are currently in production. The other, the McCaa, has a nominal operation time of only 2 hours and is no longer in production but is still widely used in the mining industry, spare parts being obtained by cannibalization. By agreement with BuMines, RBA were considered to have passed the operational test in sub-freezing temperatures if they operated for at least one-half of their nominal operation times.

Six young male volunteers were each trained with and assigned to a single RBA unit for the entire period of testing; two other volunteers were trained with all three RBA types and filled in occasionally when the principal subjects were ill or administratively unavailable. Thus, each principal subject was thoroughly familiar with the operation of his RBA. This maximized the likeihood that malfunctions of the RBA were due to environmental conditions rather than to improper operation.

Operational testing was divided into two phases. Phase I tested the performance after overnight storage of the RBA at the testing temperature (cold soaking). Phase II tested the performance after overnight storage at +15°C. All of Phase I testing was completed before Phase II began; tests successfully passed in Phase I were not repeated in Phase II. The sequential testing design is shown in Figure 1. The initial Phase I temperature was -20°C. The RBA that passed that test were then tested at colder temperatures, while those that failed the initial test were tested at warmer temperatures.

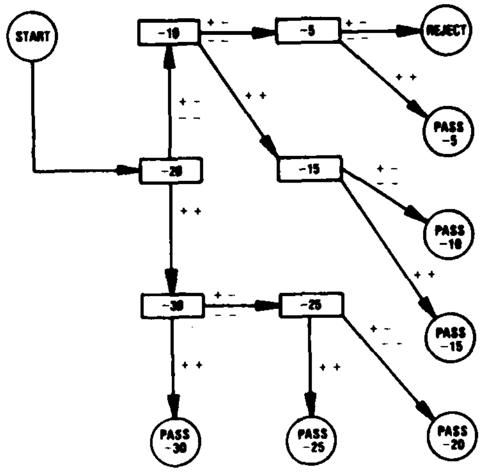
FIGURE 1. TEST SCHEDULE FOR PHASES I & II: AIR TEMPERATURES IN DEGREES CELSIUS.

CODE:

++ = BOTH UNITS SUCCESSFULLY COMPLETE TEST.

+− = ONE UNIT SUCCESSFULLY COMPLETES TEST.

−− = BOTH UNITS FAIL TEST.



Tests were conducted in a large climate-controlled chamber at the specified temperature $\pm$ 0.5^{o}C with air motion 60-80 m/s. After connection to the measuring instrument cables, subjects performed a 40 min cycle of treadmill work and rest: 20 min slow walk (VO_2 = 1.1 $\pm$ 0.1 l/min), 10 min fast walk (VO_2 = 2.0 $\pm$ 0.2 l/min) and 10 min rest, repeated until RBA failure occurred or one-half the nominal operation time had occurred.

Subjects' rectal and 11-point skin temperatures were continuously monitored for safety along with the following RBA parameters: temperature at 6 points within the breathing circuit, maximum inspiratory and expiratory pressures within the face mask, O_2 and CO_2 concentrations in inspired air and O_2 cylinder pressure. Subjective ratings of respiratory effort, body thermal sensation and comfort were also obtained. Leaking of the seal between the user and the face mask was tested during each rest period by inserting the head into a series of three boxes of ~1 m^3 volume. One box of the three contained a nearly

saturated concentration of isoamyl acetate (banana oil), which was readily detected under control conditions if a finger was thrust through the mask seal. During the environmental tests, no mask leakage was ever detected, indicating good seals on all three types of RBA at all temperatures.

Following each test, RBAs, were washed, rinsed with disinfectant and then rinsed with alcohol and dried inside and out with warm air from hair dryers. This was necessary to prevent any residual moisture in or on the instrument parts from freezing and causing malfunctions prior to test. Preliminary testing showed that the RBA would not work properly under freezing conditions unless they were dry at the start of each test.

Table 1 shows the operating times in Phase I (after overnight cold-soaking). The Scott units performed the best, operating for 2.3 - 3.3 hours at -20°C. The Drager-National and McCaa units each operated for at least half their normal times at -10°C, but not at any colder temperatures.

TABLE 1

Operational Times (Minutes) for RBA's after Overnight Storage at Each Testing Temperature (Cold-Soaking)

Model		Testing Temperature (°C)				
RBA		-10	-15	-20	-25	-30
McCaa	1	75*	30	23	--	--
	2	67*	28	27	--	--
Scott	1	--	--	200**	70	--
	2	--	--	141*	190*	--
Drager	1	160**	33	5	--	--
	2	160**	10	0	--	--

- - = Unit not tested at this temperature.

* = Unit passed test, but failed at this time.

** Unit passed test and was still operational when test terminated.

Failure modes were quite different for the three instruments. The Scott units did not operate at -25°C or below because the pressure in the cold-soaked O_2 bottle was reduced below that needed to activate properly the O_2 dispensing mechanism and alarm unit. As a result, when the Scott unit was first turned on, the O_2 pressure alarm signal valve opened properly, but did not shut off immediately at it should have. This vented an undetermined amount of O_2 from the cylinder, reducing the supply below that needed for half normal operation times. This problem occurred with both Scott units and appeared to be inherent in the design.

The Drager-National and McCaa units failed because they did not properly scrub CO_2 from the breathing circuit at -15°C and below. The Drager-National units failed to properly scrub CO_2 from the start of each test when cold-soaked. However, if the scrubber could stumble along for 45 to 60 min without allowing the inspired CO_2 concentration to exceed the cut-off values (4% at any time, 3% for no more than 2 min or 2% for no more than 10 min), it would warm up enough to continue functioning properly until the O_2 supply ran out. On other hand, the function of the McCaa unit scrubber progressively deteriorated from the start of each test at temperatures of -15°C and below. This permitted CO_2 to build up to excessive levels, particularly during the fast walk portion of the work-rest cycle. The colder the temperature, the faster the build up.

Table 2 shows the operating times in Phase II (after overnight storage at +15°C). Again the Scott units performed the best, operating for 3.0 - 3.5 hours at -25°C. At -30°C, one unit would no longer deliver oxygen to the mask after 71 min, although the cylinder pressure was still 450 psi, a bit less than one-third full. The cause of the malfunction could not be determined. On a re-test, ice built up in the expired air line. However, the other unit performed properly for 120 minutes.

TABLE 2

Operational Times (Minutes) for RBA's after Overnight Storage at +15°C

Model RBA		Testing Temperature ($^{\circ}$C) -15	-20	-25	-30	
McCaa	1	98*	67*	--	--	
	2	98**	64*	--	--	
Scott	1	--	--	187*	71	
	2	--	--	211**	70	(retest)
Drager	1	--	136*	120**	99	
	2	--	136*	102	160*	

- - = Unit not tested at this temperature.

* = Unit passed test, but failed at this time.

** = Unit passed test and was still operational when test terminated.

The Drager-National and McCaa units both operated for one-half normal time at -20°C. At both -20 and -25°C one Drager unit progressively iced up until breathing effort became intolerable at 134 and 102 min, respectively, but the other unit remained operational for more than 120 min both times. The McCaa units always failed because of progressive build-up of CO_2 to excessive levels. At -20°C, both units exceeded 60 min by 4 and 7 min, which leaves little margin for error. At -15°C, both units performed successfully for 98 minutes, whereupon one unit exceeded the CO_2 criteria. This temperature thus appears to be a safer lower limit.

Respiratory pressures within the face mask generally ranged from $\pm$5 cm H_2O at rest to $\pm$10 cm H_2O during the fast walk. Maximum inspiratory pressures normally were within 2 - 3 cm H_2O of maximum expiratory pressures. When either of the respiratory pressures exceeded 15 cm H_2O, subjects complained of difficulty breathing and very soon refused to continue the test. These high pressures were caused by frost accumulation within the breathing hoses to the mask.

During the fast walk, average pressures were 6 - 7, 9 - 10 and 13 – 14 cm H_2O for the Drager, Scott and McCaa units, respectively. Face mask pressures correlated only with the work rate and not with CO_2 or O_2 concentrations or breathing circuit temperatures.

Breathing circuit temperatures, O_2 and CO_2 concentrations and O_2 bottle pressures were recorded and the details are being graphed for inclusion in the draft report to BuMines. Analysis of subjective data has shown that respiratory effort is excessive only when respiratory pressures exceed 15 cm H_2O.

The final report for BuMines is presently being drafted from which two manuscripts are envisioned. One will report the operational capabilities of the tested RBA under cold conditions and the other will report the operating pressures observed within the face mask and their correlation with subjective responses. The latter manuscript will serve as design guidance for the development of future closed-circuit breathing devices to be used in the cold.

(83055)

RESEARCH AND TECHNOLOGY WORK UNIT SUMMARY	1. AGENCY ACCESSION: DA OC 6121	2. DATE OF SUMMARY: 79 10 01	REPORT CONTROL SYMBOL: DD-DR&E(AR)636

3. DATE PREV SUM'RY	4. KIND OF SUMMARY	5. SUMMARY SCTY	6. WORK SECURITY	7. REGRADING	8a. DISB'N INSTR'N	8b. SPECIFIC DATA-CONTRACTOR ACCESS	9. LEVEL OF SUM
79 04 30	D. Change	U	U	NA	NL	☒ YES ☐ NO	A. WORK UNIT

10. NO./CODES:	PROGRAM ELEMENT	PROJECT NUMBER	TASK AREA NUMBER	WORK UNIT NUMBER
a. PRIMARY	6.27.77.A	3E162777A845	00	055
b. CONTRIBUTING				
c. CONTRIBUTING	CARDS 114f			

11. TITLE (Precede with Security Classification Code) (U)Army Team Health and Efficiency Under Environmental and Situational Stress in Simulated Combat Operations (22)

12. SCIENTIFIC AND TECHNOLOGICAL AREAS 013400 Psychology; 016200 Stress Physiology; 005900 Environmental Biology; 007900 Occupational Medicine; 002300 Biochemistry

13. START DATE	14. ESTIMATED COMPLETION DATE	15. FUNDING AGENCY	16. PERFORMANCE METHOD
76 10	CONT	DA	C. In-House

17. CONTRACT/GRANT

a. DATES/EFFECTIVE: EXPIRATION:

b. NUMBER: NOT APPLICABLE

c. TYPE: d. AMOUNT:

e. KIND OF AWARD: f. CUM. AMT.

18. RESOURCES ESTIMATE		a. PROFESSIONAL MAN YRS	b. FUNDS (In thousands)
FISCAL YEAR	PRECEDING 79	8	346
	CURRENT 80	9	385

19. RESPONSIBLE DOD ORGANIZATION

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SOCIAL SECURITY ACCOUNT NUMBER:

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NAME: 955-2822 DA

21. GENERAL USE

Foreign Intelligence Not Considered

22. KEYWORDS (Precede EACH with Security Classification Code) (U)Team Performance; (U)Environmental Stress; (U)Sustained or Continuous Operations; (U)Fatigue, Mental; (U)Psychomotor & Cognitive Functions; (U)Motivation.

23. TECHNICAL OBJECTIVE, 24. APPROACH, 25. PROGRESS (Furnish individual paragraphs identified by number. Precede text of each with Security Classification Code.)

23. (U) In TRADOC standard scenarios, Army units may deploy to harsh climates to fight for five or more days without rest. This work unit quantifies, correlates and describes in a critical military context the interaction of: 1) harsh climatic condition; 2) common military stressors such as mission demands, noise, crowded work space, and sustained operations with recurrent sleep disruption or deprivation; 3) the acute physiological, biochemical, symptomatic and psychosocial status of functioning team members; 4) individual and team operational effectiveness over time.

24. (U) FDC teams from line Field Artillery units are tested for extended periods in naturalistic combat simulations as a "model" command/control and communications system. Multidisciplinary data collection and correlation are done to assess the operational as well as medical cost to teams functioning under stress, determine rates of recovery following exposure, identify predictors of operational degradation, establish mechanisms of action, and test prophylactic or therapeutic interventions. Collaboration in Operational and FDTE Tests of other DA agencies extends the methodology to other Army teams under field stress conditions.

25. (U) 78 10 - 79 09 (1) Data analysis of the 1977 studies of four 82d Airborne Division FDC teams will soon be completed. Findings regarding team and individual performance sleep EEG, neuroendocrine responses and changes in physical fitness measures were presented before three scientific proceedings, and the biochemical findings were published. Team interactions and compensatory mechanisms are being studied by a modified Bale's Interaction Process Analysis. (2) Consultation was given to TCATA and USAFAS in the design and test methodology of FT 444, a proposed field test to determine whether 155 mm howitzer crews can achieve and maintain the unprecedented levels of firing (simulated), movement and defensive posture required over the first 8 days of the SCORES European scenario. Scientific contributions and personnel resources from this work unit are included in TCATA's FT 444 Outline Test Plan.

*Available to contractors upon originator's approval.

DD FORM 1498, 1 MAR 68 PREVIOUS EDITIONS OF THIS FORM ARE OBSOLETE. DD FORMS 1498A, 1 NOV 65 AND 1498-1, 1 MAR 68 (FOR ARMY USE) ARE OBSOLETE.

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Program Element: 6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE

Project: 3E762777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance

Work Unit: 055 Army Team Health and Efficiency Under Environmental and Situational Stress in Simulated Combat Operations

Study Title: Field Artillery 155 mm Howitzer Crew Health and Effectiveness in a High Intensity Simulated Sustained Combat Exercise

Investigators: James W. Stokes, M.D., LTC, MC and Louis E. Banderet, Ph.D.

Background:

The standard Training and Doctrine Command (TRADOC) SCORES European scenario (1) projects sustained combat against numerically superior mechanized forces whose doctrine calls for continuous day and night attack by echelons. Predicted artillery firing rates, driven by new developments in target acquisition and computerized fire direction and by the potential numbers of friendly and hostile forces, indicate that the 155 mm howitzers which provide the direct support to US Army maneuver units could be called upon to fire for over a week at rates 50% or more greater than the highest 24 h rates from WWI, WW II and the Korean War. Furthermore, unlike those historical battles where the artillery generally functioned in static, relatively secure positions, modern war would require the howitzers to move to new locations up to 8 times/24 h to avoid enemy counterfire or ground forces, and to maintain exceptional camouflage and perimeter defenses. At best, there would be little opportunity for fragmented naps under adverse conditions for any of the 10 men or fewer who man each howitzer. Yet their critical tasks cover a wide range of demands, including vigilance in isolated listening posts, digging, vehicle driving and maintenance, communicating by wire or radio, preparing new classes of projectiles for firing, setting precision fuses and gun sights and very heavy physical labor. Since ammunition handing facilities in the field have not kept pace with technological developments, many tons of 95 lb projectiles would have to be handled manually each day by the guncrews during resupply as well as when firing.

In view of the SCORES projections, the Commander of TRADOC expressed interest in an 8-day field study to determine whether the current crew-size could sustain such unprecedented work loads. The TRADOC Combined Arms Test Activity (TCATA) at Fort Hood, TX was tasked as the test agency for this "Field Artillery Crew Test" (FACT), with the US Army Field Artillery Center (USAFAC) at Fort Sill, OK as proponent. The issues to be addressed included firing rate and acuracy (i.e. the physical fitness and stamina needed to move the great volumes of ammunition and the mental alertness needed to fire the howitzer); however, the other essential artillery functions of communication, movement, security and maintenance could not be neglected. In principle, the problem also involved the effects of frequent impulse noise and blast overpressure on the human body and mind; however, this raised additional issues of test subject safety which might best be addressed in a different setting.

Progress:

In November 1979, TCATA consulted with USARIEM's Health and Performance Division about test design for the 8-day field experiment. We arranged for representatives of TCATA to present the problem at The Technical Cooperation Program (TTCP) Action Group UAG-4 symposium on Performance Limits in Extended Military Operations (San Antonio, TX, Dec 79). The TCATA test plan involved the firing of live ammunition, which would cost over one million dollars as well as causing potential environmental impact and risk to the test subjects. It was the consensus of the behavioral scientists at TTCP that most of the artillery performance objectives of the FACT, as well as human biomedical/psychological data, could be obtained from a study in which firing was only simulated. Subsequently, the Commanding General of TRADOC indicated that alternatives to a live-fire test (e.g. a "time and motion study") should be considered.

In January, assistance was requested by TCATA and USAFAC in drafting the Outline Test Plan (OTP) for the Field Artillery Crew Test. As completed, the OTP for FT 444 (2) proposed an initial dry-fire 8-day sustained field test (Phase I); Phase II, a live-fire replication, would be conducted only if the results from Phase I were not considered conclusive.

One objective in the OTP was "to investigate the effects of physical,

psychological and fatigue factors on selected test unit personnel." USARIEM proposed to collect and analyze data of the following kinds: a) medical complaints of the howitzer crewmen (including accidental injury, orthopedic signs and "overuse syndromes"); b) the treatments given by the battery medics, recording any restrictions on activity ("profiles") and following-up patients evacuated to medical facilities or discharged to garrison; c) somatic symptoms, mood and fatigue, collected by periodic questionnaire survey; d) task distribution, leadership techniques, team social interaction, and eating, resting and sleeping behaviors, collected by systematic observation; e) physical stressors in the environment (temperature, humidity, noise, etc); f) physical fitness (aerobic endurance and muscle group strengths as well as standard Army Physical Training Test scores) pre-test and perhaps also at several times during and after the sustained operation; g) if feasible, measures of human energy expenditure (oxygen uptake) during selected phases of the operation.

Provision for USARIEM investigators, technicians, and equipment were written into the OTP, as well as a requirement for sixteen field medics (91B) as assistant biomedical evaluators. The information collected by USARIEM would aid in interpreting the operational performance of the howitzer crews. If the crews failed to achieve the unprecedented firing rates, it would be important to document the extent that this was due to musculoskeletal incapacitation by the physical demand, to fatigue interfering with the execution of fine psychomotor skills, or to failures in team coordination and motivation. Equally important would be to follow how personnel were tasked within the team to perform those gun-crew functions which were not driven by external demand. Previous research has indicated that these are the functions which suffer most under stress, which go unprobed by most test designs, yet which could lead to sudden system failure or unit destruction in actual combat.

The proposed physical fitness testing would be conducted by the USARIEM Exercise Physiology Division (principle investigator, CPT James Wright, Ph.D.) to supplement their ongoing mission responsibility to establish physical fitness standards for all Army MOSs. The 13B MOS (Field Artillery gunner) is typical of those MOSs which demand maximum muscle strength and moderate aerobic endurance. The FACT would provide opportunity to validate the physical fitness standards for MOS 13B in a field setting against the standard SCORES scenario requirement for repeated performance of the criterion tasks (which involve

primarily lifting and carrying) over a sustained period under difficult environ mental conditions and in a context of other demanding work. Of special concern is whether the PT standards and training programs that are being established will provide sufficient protection against overuse syndromes when the troops must suddenly begin to work at a realistic "worst-case" pace, or whether many troops will become temporarily less able to perform physical tasks. Medical review and follow-up of test subjects who are put on profile or evacuated from the study is necessary to judge whether they would have been so favored in a desperate combat situation and when they could have returned to duty. Finally, direct assessment of energy expenditure would permit generalization of physical fitness findings from the FACT to other, non-artillery MOSs.

It became clear during the meeting to draft the OTP that USARIEM had unique experience in the design and execution of dry-fire artillery scenarios to assess performance changes over time. At first, both TCATA and USAFAC regarded Phase I as only a dress rehearsal for a necessary live fire study and did not expect it to approach the physical work demands and stresses required to answer the issues. We convinced the TCATA officer assigned to the test that the manipulation and preparation of actual (but non-explosive) ammunition was essential in the dry-fire test and could be accomplished if sufficient controller personnel were allocated. We also stressed the importance of simulating the noise of firing, although this need not involve potentially harmful decibel and blast overpressure intensities.

At the request of the TCATA test officer, we subsequently wrote a memorandum, subject: "Motivation and Morale Factors in the FACT." Points covered included discussion of general principles and specific recommendations for the design and execution of the field study to achieve high motivation in the test subject troops even though live ammunition was not fired. Another memorandum was provided to the USAFAC's Doctrine Team, Combat Developments Directorate, subject: "Proposed Specifications and SOP for the Scenario for the FACT." This suggested methods of scenario design and event-matching whose value for reducing variance and simplifying data analysis had been demonstrated in our fire direction center team studies. The memorandum indicated a number of variables in unit SOP or test execution which should be standardized or controlled if the objective was to assess changes in team and individual capabilities due to physical and psychological fatigue. We also urged

that the mission load in the FACT should represent a reasonable "worst-case" adaptation of the SCORES European scenario rather than some lesser work load selected to conform to estimates of what the crews could accomplish or to reduce expenses.

Concern over the resources needed for the test interfered with further planning of the FACT. As no test location or test unit had been specified by May 1979, the Test Schedule and Review Committee (TSARC) deferred further consideration of FT 444 until this could be resolved. A meeting at USAFAC (with USARIEM representation) resulted in a message to TRADOC dated 25 June, recommending reconsideration of Fort Hood (previously ruled out by TRADOC) as the test site. The message also distinguished the dry-fire study as an effort in its own right, (designated "FACT I") which would involve a provisional 8-howitzer battery. The contingent nature of any live-fire follow-up ("FACT II") was also emphasized. If FACT II was conducted, it would only involve a 4-howitzer platoon.

In late July, USARIEM was invited by USAFAC to take part in a symposium at Fort Sill which was concerned with improving the computer simulation (wargaming) of the psychological "suppressive effects" of artillery and other weapons fire. It was evident at that time that key officers at USAFAC still believed that FACT would have to resort to live-fire to address the ultimate issues, although they then questioned the costliness of such a study.

On 26 September, TRADOC concurred with the proposal for a dry-fire FACT I study, but not with conducting it at Fort Hood. FT 444 will be considered in the fall TSARC process; it is understood that FACT II, if conducted, need not be held at the same location nor utilize the same test unit as FACT I. USARIEM will continue to follow the planning of the experiment and provide any assistance we can in test design and scenario construction. If the Field Artillery Crew Test is conducted, the USARIEM's Health and Performance Division and Exercise Physiology Division expect to collect biomedical and psychological data.

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2. Outline Test Plan for Field Artillery Crew Test (FACT) 79-FT-444. TRADOC Combined Arms Test Activity (ATCAT-OP-T), Ft. Hood, TX.

Program Element:	6.27.77.A ENVIRONMENTAL STRESS, PHYSICAL FITNESS AND MEDICAL FACTORS IN MILITARY PERFORMANCE
Project:	3E162777A845 Environmental Stress, Physical Fitness and Medical Factors in Military Performance
Work Unit:	055 Army Team Health and Efficiency Under Environmental and Situational Stress in Simulated Combat Operations
Study Title:	Fire Direction Center (FDC) Team Health and Efficiency Under Environmental and Situational Stress in Simulated Combat Operations
Investigators:	Louis E. Banderet, Ph.D., James W. Stokes, M.D., LTC, MC and Ralph P. Francesconi, Ph.D.

Background:

The efficiency and well-being of Army command/control and communications teams may be especially vulnerable to the psychophysiologic stresses of sustained combat or climatic extremes. Since mission demands require that such teams are nearly always occupied, their critical perceptual, cognitive, interpersonal and psychomotor tasks are potentially sensitive to sleep loss and subtle physiological disruption (1). To address these complex issues, a laboratory simulation was developed at USARIEM to study actual Field Artillery fire direction center (FDC) teams as they performed a broad array of their normal functions under various environmental and high-intensity task conditions (2). This approach capitalized on pre-existing training, professional pride, social support systems and military task organization, factors known to influence physiological as well as psychological responses to stress (3). A highly structured scenario-script organized into equivalent 6 h modules of FDC mission demands permitted assessment of team and individual performance for correlation with physiological, social, and behavioral measures.

In 1977, a multidisciplinary study was conducted by the US Army Research Institute of Environmental Medicine (USARIEM), the Naval Health Research Center (NHRC) and the Walter Reed Army Institute of Research (WRAIR). This study was to evaluate the FDC simulation as an experimental model for future studies of environmental stress and associated therapies (USARIEM), physiological and social factors implicated in combat exhaustion (WRAIR), and sleep

logistics (NHRC). Natural FDC records were preserved and many activities during the simulated operations were recorded on audio and video tape for subsequent analysis. The simulation, methods, test design, and some results have been reported elsewhere (4,5,6,7,8).

In brief, four 82d Airborne Division Battery FDC teams were studied in the laboratory simulation under comfortable environmental conditions. All teams were familiarized with simulation; this included an initial 3 h orientation followed by 8 h practice trials on 3 successive days with the standard scenario mission work load. Teams 1 and 4 then underwent a single sustained challenge and were told the challenge could last 86 h; they terminated voluntarily after 48 h (at 0700 h) and 45 h (at 0400 h), respectively. Teams 2 and 3 underwent two 38 h sustained challenges separated by a 34 h (nigh-day-night) rest interval; both teams completed all challenges although a chart operator from Team 3 withdrew voluntarily after 6 h in the second challenge.

In general, team output performance conformed to predictions from field experience and the scientific literature (1). Specifically, unplanned fire mission events showed few changes in accuracy but more varied and increased latencies with time on task. These missions were externally cued by scenario role-players, involved most or all team members for brief periods, and received prompt feedback for inadequate performance. In contrast, fire mission events which required preplanning of fire data were more vulnerable. These missions required that team members work both independently and collaboratively amidst other urgent demands; such missions received either no feedback or delayed feedback or inadequate performance. Teams 1 and 4 showed progressive deterioration in accuracy of firing data computed for such events (due primarily to omission of correction factors), increased latency of preplanning tasks, and an increased numbers of preplanned targets which were never completed. In addition, Teams 1 and 4 showed increased latencies with fire mission events for which prior preplanning was presumed. These trends became marked after 36 h in Team 1 and after 24 h in Team 4. Teams 2 and 3 showed only slight indications of these trends; the most pronounced were in the latter hours of Team's 2 second 36 h challenge. These differences presumably reflected the shorter durations of sustained trials for teams 2 and 3, their expectancies for challenges not to exceed 42 h, and also greater initial mastery of preplanning requirements. All teams showed progressive tendencies to neglect less essential tasks.

This report will describe recent analyses and present new data which support and extend past conclusions about team (system) output, relate team output to individual team member performance, assess changes in social interaction and communications, and evaluate the neuroendocrine response (urinary cortisol) of members of Team 4.

Progress:

This past year efforts were concentrated on the development of three new analyses of data from the 1977 simulation studies. In general, these analyses provide information on individual task performance for selected members of the FDC, measures of the spontaneity, (as well as quality and timeliness) of system (team) output information, and the frequency, quality, and type of verbal interactions among the FDC team members. Substantial progress was made on these analyses and preliminary data are emerging; some of these initial data will be arrayed to provide a sample of the kind of information which will be available for all four studies.

The Computer Records (COMPREC) analysis is based upon information from the Record and Fire Form (DA 4504). This form is a natural, historical record maintained by the Computer (sergeant) in Army fire direction centers for each target engaged. This analysis will aid us in determining the completeness and accuracy of each Computer's record keeping, accuracy of derived values generated by other members of the FDC team, ballistic data and associated correction factors and changes made by the Computer as he completed the record.

Shown in Figure 1 is the no. recorded/no. not recorded ratio for a selected variable, e.g. fire mission subsequent adjustment information, for the Team 4 Computer. In the first 6 h of the simulation the Computer recorded approximately five times more of this information than he did not record. Subsequently, this behavior dropped dramatically so that after 24 h in the simulation it was 1/20 of initial values. This information is not absolutely essential for the performance of the Computer's duties; however, in the event of discrepancies or questions about the event such information would greatly assis the Computer and Fire Direction Officer in evaluating the information. This behavior is similar to that of the Team 1 Computer but contrasts with the

Computers from Teams 2 and 3 who generally recorded such information. Considered with other information from Team 4, these data indicate that after approximately 12 h in the simulation, changes in the Computer's task performance were apparent.

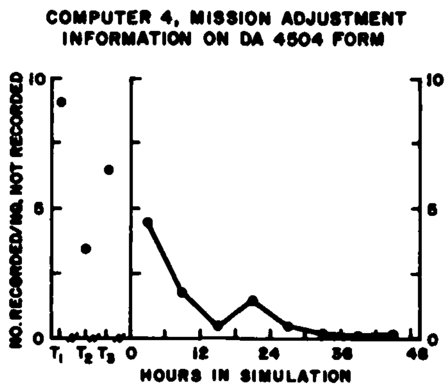


Figure 1. The (information recorded/information not recorded) ratio for subsequent adjustment mission information for Team 4's Computer is shown as a function of hours in the simulation. Values for each of the three training sessions are also shown.

The Successive Iterations (SIT) analysis evaluates mission communications occurring between the FDC Computer and role players simulating the firing battery (guns). Specifically, we can determine how the Computer manages and controls the firing battery, his individual performance, accuracy of initial and successive ballistic data for preplanned targets, and the percentage of pre planned data generated spontaneously rather than in response to an external, imminent mission demand. We are also encoding indices reflecting impairments in attention, memory, and the ability to process information.

In performing the SIT analysis project personnel listened to audio-compressed recordings and encoded information directly onto computer-formated coding sheets. Automated audio-compression equipment and procedures were developed this past year to facilitate the analysis. The technique used computer-battery communications and time code from 2 channels of the master 20-channel audio records. This information was compressed by eliminating any portions of the original recording that did not contain speech information for ≥ 7 sec. The compressed information was recorded onto a small 2-channel audio recorder; on that recording the communications appeared nearly continuous. Approximately 4:1 compression ratios were realized in compressing the SIT computer-battery telephone communications. Compression of other information, e.g. radio net communications, will yield even greater ratios. The audio compression technique is a beneficial and time-saving procedure since personnel 1) listen to only tape portions where there is speech information, 2) can analyze information independently of other personnel since smaller, less costly recorders can be used or playback analysis, and 3) can perform a number of different analyses simultaneously since they are not limited by accessibility to the more expensive 20-channel recorders. In future FDC studies or related projects this technique will allow personnel to perform many of the labor-intensive data reductions shortly after the conclusion of the study series.

In doing the SIT analysis, whenever a call for a fire mission against a preplanned target or a specification of priority for one of those targets occurred, we tabulated whether preplanned data for that target were previously at the guns. If data were already at the guns, the FDC was prepared; if data were sent to the guns after the event was initiated, the FDC was unprepared. Three functions from the SIT analysis are arrayed in Figure 2. The solid circle and triangle functions show the no. prepared/no. unprepared ratios for missions involving preplanned targets and for the priority target specifications events, respectively. Both functions considered all such events even if requests for the same preplanned target occurred in more than one event.

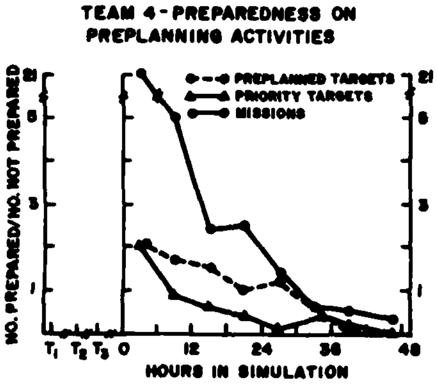


Figure 2. Preparedness on various measures of preplanning are shown for Team 4 as a function of hours in the simulation. Three measures highlighting different aspects of preplanning are shown: Preparedness on missions involving preplanned targets (o—o), preparedness for priority target specifications (Δ—Δ), and for all preplanned targets (•- -•).

In contrast, the no. prepared/no. unprepared preplanned target ratio utilizes only the initial request for each preplanned target whether that request was a fire mission or a priority specification. FDC preparedness was tabulated like the previous measures. Moreover, if a preplanned target was never requested but preplanned data were generated, credit was given to the FDC for being prepared. In all three functions the preplanning "preparedness" of Team 4 markedly decreased with increased h in the simulation. For the mission and priority target specification measures some of the largest deteriorations were observed in the first 12 h. Preparedness for missions appears better maintained than for the priority target measure and is probably because more time passed before a preplanned target was requested in a mission than before it could be specified as a priority target. For the preplanned target measure, the fact that each preplanned target is only considered once and that this measure is based on either a mission or priority target specification probably accounts for the differences in this function as compared with the other two. Scientifically, the

preplanned target ratio is the best performance measure; however, the mission and priority target functions do describe specific operational consequences associated with failures in the team's preplanning activities.

Shown in the upper portion of Figure 3 are total changes or corrections specified to the guns by the Team 2 Computer. These included changes such as method of fire, charge, time, deflection, quadrant, and other data elements.

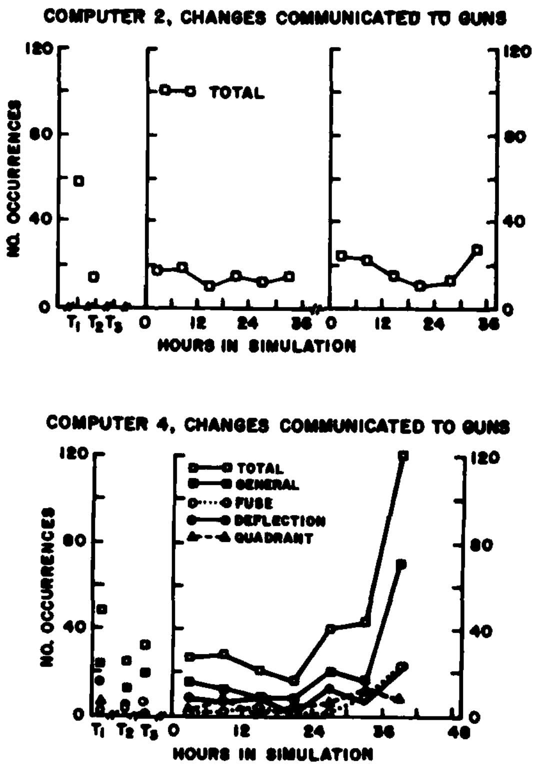


Figure 3. Changes specified to the guns are shown as a function of increased h in the simulation. Data for Team 2 are shown in the upper portion; whereas, Team 4 data, in the lower portion. Total changes in each figure are shown as the solid dot functions. Specific types of changes i.e. subcomponents of total changes, are also shown for Team 4.

These changes were initiated by the FDC Computer and reflected things which he felt required alterations; many things probably went unnoticed especially with increasing h in the simulation. In Team 2's data there was evidence of a training effect, but data for this measure appeared remarkably stable during the first 36 h. During the second 36 h challenge there were variations with a slight increase during the last 6 h. Specific types of changes, i.e. subsets of total changes, were not plotted due to the low frequency of total changes.

In the lower portion of Figure 3 are equivalent Team 4 data and plots for specific types of changes. On all measures there was a small increase between 18 and 36 h with a marked increase in all changes, except quadrant, in the 6 h prior to the team's termination. It should be noted that changes in quadrant (the last data element sent before firing the guns) did not increase with h in the simulation. This probably resulted since the mission was normally fired shortly after the quadrant was sent and the sending of quadrant was generally synonymous with a command to fire the guns. Hence, the Computer had little time to identify or specify changes, and sending of quadrant implied commitment to the information already sent.

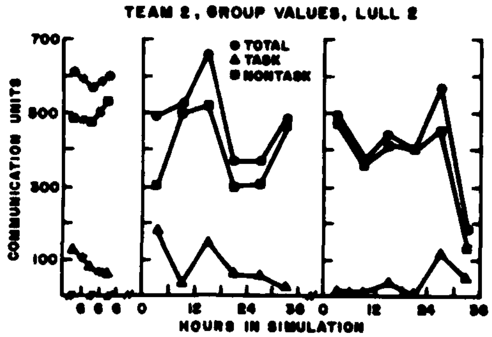
We had also hoped to develop a measure which we called prompts. These were errors, inconsistencies, and obvious omissions which were noticed by the battery role players and fed back to the FDC. Preliminary perusal of these data indicated that our various role players were not consistent enough in their detection and feedback of these mistakes to use this information as a measure of FDC performance.

The Bales Interaction Process Analysis (IPA) of verbal communications is a well established analysis for determining group process and group structure from the quality of interactions (9). Total communications, task/nontask ratios, communications initiated and received by various personnel, number of supportive communications, and other indices can be determined. We will look at factors which may be critical determinants of a team's compensations/decompensations responses and will also evaluate these measures as indicants of morale, willingness to work, and individual and group well-being.

When the scenario scripts were written, two "lulls" were incorporated in every 6 h scenario module as standard events. Specifically, these lulls were 12-min periods in which there were no new mission demands made upon the team from radio messages; however, irrelevant radio traffic did continue during these

periods. For our analysis of this information, Bales's procedures and categories were modified slightly. We retained Bales's 12 categories, but added a 13th category for any task communications which followed normal FDC communication SOP (task communications). If a communication described some aspect of the task, task procedure, or derived values but did not follow SOP, it was scored utilizing one of Bales's traditional categories. Our extra category was included to isolate predictable task determined communications sequences, capture the tendency of individuals to deviate from task communication's SOP, and to evaluate how the team processed task information not conforming to SOP with increasing time in the simulation.

Shown in Figure 4 are data from Teams 2 and 4 for information collected during the second lull period in each 6 h scenario module various. Communications from all five individuals in the team have been summed for group values; Figure 4 shows group values for total task and nontask communications. Total communications during the lulls ranged from 200 to 650 for Team 2; Team 4's communications were less varied, i.e. 400 to 700. For both teams usual values were from 350 to 500. Total communications data for both teams indicated a circadian rhythm, especially evident in the first 24 h for each team. This rhythm is not apparent in the second challenge of Team 2. In this challenge several members of the team entered the simulation after having slept poorly the previous evening. The reduced amplitude of communications in the first 24 h of the second challenge for Team 2, which followed a prior evening of altered sleep schedules, is consistent with the reduced amplitude observed for Team 4 for 24 to 42 h following a prior night of sleeplessness in the simulation.



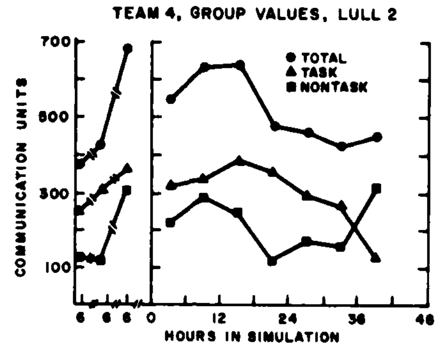


Figure 4. Group communications during each 2nd scenario "lull" with increased hours in the simulation. Shown in the upper portion of the figure are data for Team 2; Team 4's data are in the lower portion. Total communications (o—o), task communications (Δ), and nontask communications (O) are shown. Total communications for each group are similar and range from 300 to 700 units.

Shown in Figure 5 are task/nontask ratios and unprocessed preplanned demands for both Teams 2 and 4. These teams differed markedly in how lull intervals were spent. Both Figure 4 and 5, especially the task/nontask ratio, indicate that Team 4 engaged predominantly in task communications. In contrast, Team 2 used the lull intervals to rest and to interact with each other. This is dramatically shown by the fact that Team 2's task/nontask ratios were typically ≤ 0.4; whereas, Team 4's ratio was ≥ 1.0, except in the lull 3 h prior to

termination. With increasing unprocessed preplanned demands, commnications became more task oriented for both teams up to some limit. In Team 4 after 24 h in the simulation there were marked increases in unprocessed preplanned demands but the task communications decreased markedly. This trend reflected the fact that fewer and fewer communications describing the task followed SOP and the fact that individuals began to use these period for discussing other types of information. Although teams often remained concerned with task requirements, their behavior became much less goal directed and their non-standard communications reflected this. Such deviations sometimes resulted in numerous confusions, as well as increased effort and attention in order to accomplish task demands. Although preliminary and many other analysis remain to be done, these data do suggest that different teams can be characterized on the basis of communications occurring during these lull intervals. Furthermore, the content and type of communications bear some relationship to the operational and performance capabilities at that time. In the future the contribution of various individuals to the group's communications will be examined and other measures of communications and group process will be explored.

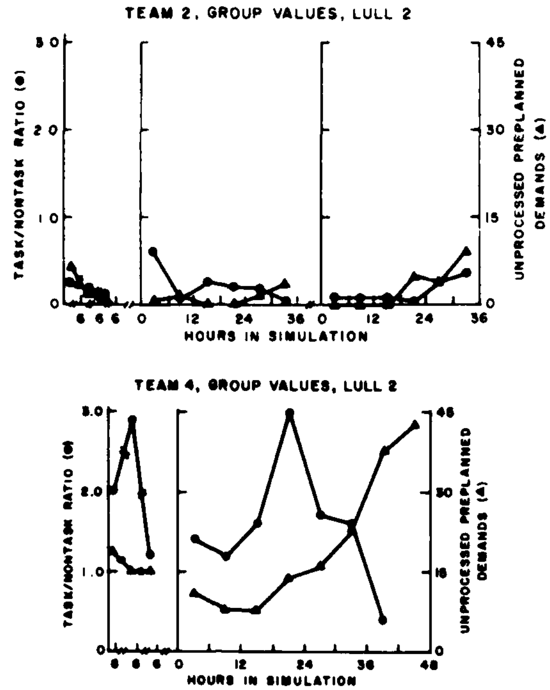


Figure 5. Shown in Figure 5 are task/nontask ratios (O) and unprocessed preplanned demands (Δ) for Teams 2 and 4. Data for Team 2 are in the upper portion of the figure; Team 4 data in the lower portion. The ordinants are scaled the same so that team comparisons can readily be made.

Urine samples collected from Team 4 during a continuous 96 h period in the familiarization (control) week and throughout their sustained operation scenario were analyzed for cortisol using a radio-immunassay procedure during FY 79. Quantitation of 17-hydroxycorticosteroids (17 OHCS) and total catecholamine excretion from Teams 1 and 2 (5, 7) suggested that the single 86 h challenge "open-ended" design, in particular, elicited inherent uncertainties and psychological stresses which resulted in elevated neuroendocrine responses. While individual factors and differences might be important, it was nevertheless of interest to see whether this hypothesis was supported by data from Team 4.

Total urinary cortisol (µg/42 h) excreted by each team member is shown in (Table 1) for two 42 h collections during the familiarization week and for the seven complete 6 h epochs of the sustained operations. All collection periods began at 0600 h.

TABLE 1

TEAM 4 URINARY CORTISOL (µgm/42 h)

Subject	1st 42 h Baseline	2d 42 h Baseline	42h Test
FDO	259	361	494
COM	790*	997	1029
RTO	192	145	---
VCO	256	388	390
HCO	640*	431*	732

NOTE: * includes estimated value for one 6 h interval

Urinary cortisol of the FDO (highly experienced himself but responsible for a novice team) showed a progressive increase over the three collections, with the highest excretion occurring during the inherent uncertainty and sustained task load of the open-ended trial. The inexperienced VCO showed a similar rise during familiarization and maintained that level during the trial. Missing data limit interpretation for the other team members, but none showed decreased cortisol secretion during the sustained trial compared with the baseline collections. Team 4's data therefore are consistent with the interpretations made for Team 2, that a team's uncertainty about their ability to complete the single open-ended challenge tended to evoke increase adenocorticotrophic activity.

In addition to the new analyses undertaken in FY 79 other team output data was subjected to analyses decribed in the FY 78 Annual Progress Report. It had been observed that the importance given to a task, either by the initial instructions to the team or by the task's manifest consequences, generally did influence performance. This was confirmed by the results of queue analysis of two of the less important tasks (revising and updating) within the overall context of maintaining readiness to fire on preplanned targets. These functions are

shown in Figure 6; for comparison, the figure also shows the previously reported findings for two more important aspects of overall preplanning (covering targets from encoded lists and targets designated as having priority). Revising was expected (but not required) at the beginning of each 6 h scenario module; it involved the Chart Operators, Computer and FDO. Updating involved only the Computer and/or FDO and was expected in the middle of each module. Failure to perform either incurred only minor (between 3 and 10 mil) errors.

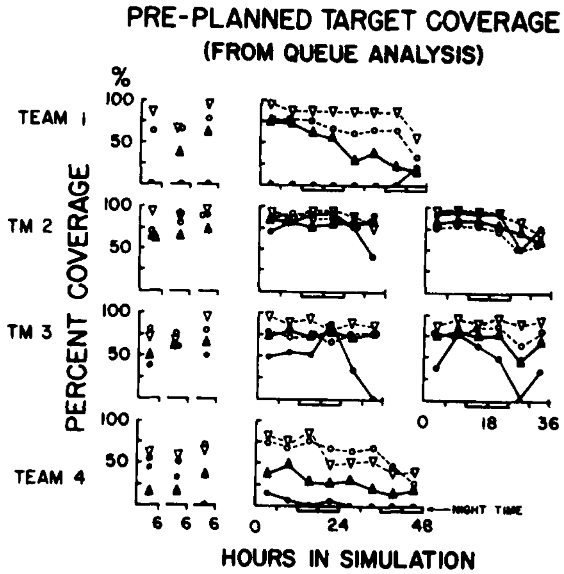


Figure 6. Percent coverages of four types of preplanned targets (determined by queue analysis of the target-minutes of mission demand) are shown for all four teams as a function of duration of operations. Coverage of targets which require the updating of firing data (a relatively unimportant task) are shown by closed circles; of targets which required revising of data (also less important), by closed triangles. Coverage of new targets from encoded lists (an important task) and of targets designated as priority (urgently important) are shown by open circles and open triangles, respectively.

Teams 1 and 4 both showed progressive declines in covering targets with revised data (Figure 6) with Team 4 achieving this coverage only about half the time at the outset. Teams 2 and 3 were about as efficient at revising as they were at the basic preplanning tasks throughout their two trials.

Updating on the other hand was almost never done by Team 2 and was quickly abandoned by Team 4 after initial token performance. For Team 2, updating coverage was less complete in the first and final 6 h of the first 38 h challenge and was the measure most sensitive to decrement in 24 to 30 h of the second challenge. For Team 3, updating was generally less efficiently performed than other preplanning tasks and deteriorated further after 28 h in each challenge. These findings support the interpretation that updating, a task which was generally done by a single team member and was not solicited or probed by external authority, was the aspect of preplanning which was most vulnerable to degradation.

During the beginning of FY 80 efforts will be concentrated in four areas which will ultimately culminate in preparation of manuscripts and technical reports: 1) finish compilation of system output and individual performance data. Special emphasis will be placed on changes or corrections, error detection capabilities, error resolutions, and the spontaneity with which various missions tasks are performed: 2) The Interaction Process Analysis will be completed using both team and individual indices: 3) Indices developed by collaborating investigators, e.g. self-rated symptoms, urine and blood chemistries, and other physiological measures will be collated with performance and other non-task measures. This effort will determine if these various measures are correlated and if biomedical measures are predictors of operational effectivenss. Lastly, 4) the utility of this experimental simulation model for future studies involving environmental stress and/or therapeutic strategies will be evaluated.

Presentations:

1. Banderet, L. E. and J. W. Stokes. Laboratory simulation studies using actual Army fire direction center teams. The Technical Cooperation Program (TTCP) Action Group UAG-4, USAF School of Aerospace Medicine, San Antonio, TX, Dec 1978.

2. Banderet, L. E. Laboratory Simulation of Intensive, Sustained Operations with Field Artillery Fire Direction Center Teams. New England Chapter of the Human Factors Society, Natick, MA, 18 May 1979.

3. Bandert, L. E. and J. W. Stokes. Artillery teams in simulated sustained combat: performance and other measures. Symposium on Variations in Work-Sleep Schedules: Effects on Health and Performance, sponsored by the Office of Naval Research and the National Institute for Occupational Safety and Health, San Diego, Ca, 19-23 Sep 79.

4. Symposium at American Psychological Association Annual Meeting, New York, NY, 4 Sep 79, entitled, Multidisciplinary assessment of a sustained operations/sleep deprivation simulation. Individual papers were:

Stokes, J. W. Laboratory simulation studies of Army FDC teams in sustained operations.

Banderet, L. E. Group and individual performance and non-task behavioral assessment.

Francesconi, R. P. Sustained operations and sleep deprivation: effects on some stress indices.

Kowal, D. M. Psychological and physiological factors affecting sustained military operations.

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1. Johnson, L. C. and P. Naitoh. The operational consequences of sleep deprivation and sleep deficit. AGARD-AG193, June 1974.

2. Stokes, J. W., L. E. Banderet, R. P. Francesconi, A. Cymerman and J. B. Sampson. The Field Artillery Fire Direction Center as a laboratory and field stress-performance model: I Position paper; II Progress towards an experimental model. In The Role of The Clinical Laboratory in Aerospace Medicine, AGARD Publication AGARD-CP-180, 1975, pp. A10-1 to A10-10.

3. Bourne, P. G. Men, Stress and Vietnam, 1970.

4. Banderet, L. E. and J. W. Stokes. Laboratory simulation studies using actual Army fire direction center teams. Proceedings of Action Group UAG-4: Performance Limits in Extended Operations (Appendix 4). Subgroup U–Behavorial Sciences, May 1979.

5. Francesconi, R. P., J. W. Stokes, L. E. Banderet and D. M. Kowal. Sustained operations and sleep deprivation: effects of indices of stress. Aviat. Space Environ. Med., 49:1271-1274, 1978.

6. Stokes, J. W. and L. E. Banderet. Performance evaluation of Artillery Teams in simulated sustained combat. In Variations in Work-Sleep Schedules: Effects on Health and Performance. Office of Naval Research and National Institute Occupational Safety and Health, 1979. (In Press).

7. Annual Progress Report FY 77, US Army Research Institute of Environmental Medicine, No. FSC MEDDH-288(R1), Dept. Army, 1978, 427-449.

8. Annual Progress Report FY 78, US Army Research Institute of Environmental Medicine, No. FSC MEDDH-288(R1), Dept. Army, 1979, 365-388.

9. Bales, R. F. Personality and Interpersonal Behavior. New York: Rinehart and Winston, Inc., 1970.

Animal Care and Animal Modeling

Investigator: John C. Donovan, D.V.M., CPT, VC

Background:

Over the years, the position of Chief, Animal Care Unit has expanded to include several areas of responsibility. These responsibilities include:

1) surgical development of new and unique animal models to support the research mission of the US Army Research Institute of Environmental Medicine (USARIEM),

2) performance of both chronic and acute aseptic surgical techniques and procedures to produce statistically significant numbers of healthy animal models,

3) administrative management of the Animal Care Facility to include the physical plant and animal care personnel in accordance with standards of the American Association for the Accreditation of Laboratory Animal Care (AALAC),

4) maintenance of the health of the laboratory animal population through a sound conditioning program, a preventative medical program for all animals and the observation, diagnosis and treatment of medical/surgical problems occurring in the laboratory animal population, and

5) chairing of USARIEM's Animal Use Committee to review and make recommendations to the Commander for his approval or disapproval of proposed research protocols utilizing laboratory animals.

Progress:

1. Veterinary Support

The majority of the professional scientific work done in fiscal year 1979 centered around preparation and modifications of the goat animal models used in support of the Altitude Research Division's protocol, "Role of Cerebral Fluids in Respiratory Adaptations to Acute Acid-Base Imbalance" by Dr. Fencl.

For this study seven new goats were procured and conditioned. Upon arrival the goats were given a physical exam, tatooed, deloused, dewormed and placed on a good diet of hay and goat chow. After an adequate time for conditioning to their new environment, work began to surgically prepare these goats for scientific study. Each goat had surgery to prepare a carotid loop and had a cisternal guide tube emplaced. Following the initial part of the goat study they would also be required to have their carotid body denervated.

Prior to collecting data on this study three other requirements arose involving the goat animal model. First, we anticipated a need to have permanent tracheostomies on the goats. Secondly, a technique for surgical denervation of the carotid body needed to be tried and perfected, and thirdly we needed a method to document carotid body denervation for the second part of the study.

In order to successfully tracheostomize a goat we enlisted the aid of a human device called a kistner button. This button enabled us to keep the tracheostomy stoma open long enough to facilitate healing without the previous problem of dried mucous and exudate obstructing the trachea resulting in pneumonia and demise. After a period of trial and error this technique was perfected and used successfully.

The method used to document denervation included the use of percutaneous pulmonary artery catheterization with a double lumen Swan-Ganz catheter and intrapulmonary arterial injection of potassium cyanide. This method will be utilized both pre and post-denervation to document a successful denervation. To date we have done four successful predenervation Swan-Ganz catheterizations and testings.

Finally, we needed to perfect a surgical technique for location, dissection and denervation of the goats carotid bodies. Cadavers were dissected to familiarize ourselves with the anatomy and help was enlisted from a colleague in Wisconsin who had already successfully denervated goats. We have just recently completed our first attempt at denervation and initial studies have documented its success.

These and other surgical procedures were performed in support of USARIEM protocols. Those procedures, their numbers, the species involved, and the nature of their use (acute or chronic) are listed in Table 1.

TABLE 1

Surgical Procedures Performed to Support Research During FY 79

Surgical Procedures	Species, Number of Procedures Acute or Chronic Preparations	
	Caprine Chronic	Acute
Tracheostomy	3	
Carotid Loop	7	
Cisternal Magna Cannula	3	
Lateral Ventricular Cannula	1	
Swan-Ganz Catheterization		4

All surgical procedures were accomplished under Work Unit 022 and were performed in support of the following protocol, "Role of Cerebral Fluids in Respiratory Adaptations to Acute Acid-Base Imbalance" Dr. Fencl.

2. Animal Use Committee

The Animal Use Committee, continuing in its responsibility to: 1) oversee the use of laboratory animals and to insure that the information sought by the use of laboratory animals is sufficiently important to warrant their use, 2) insure that the maximum amount of information consistent with good scientific research practices is obtained, 3) use the minimum number of animals necessary for scientific validity, 4) after adequate consideration of the experimental design, laboratory limitations and alternative species, select the species most suitable, and 5) insure that the description of the procedures is reasonably complete and minimizes pain and discomfort to the greatest extent possible without compromising the objectives; reviewed the following protocols:

1. "Effect of Altitude on Facilitated Diffusion of Oxygen in the Lung" - CPT Young

2. "Thermographic Evaluation of Experimentally Produced Cold Injury of Rabbit Feet" - MAJ Kelly

3. "Heat Injury: Studies on Mechanisms, Prevention and Predisposition" -Dr. Francesconi

4. "Artificial Heat Acclimatization and the Prevention of Heat Illness" - Dr. Hubbard

5. "The Alterations in Blood Coagulation, Fibrinolysis, and Platelet Aggregation in Various Degrees of Frostbite" - CPT Gadarowski

6. "Evaluation of Therapeutic Frostbite Solution" - MAJ Kelly

For each of these protocols recommendation for the approval, modification or disapproval were made to the institute commander, prior to the initiation of any experimentation.

3. Animal Care

To maintain and guarantee health of the laboratory animals, we have conducted a preventative medicine and conditioning program for each of the species. Incoming canines were examined, tatooed and dewormed upon arrival. A routine blood workup on each dog consisted of a CBC, heartworm exam and 16 parameter biochemical screen. Routine fecal analyses were performed on the dogs at six month intervals and appropriate anthelmintic therapy instituted. Rats were routinely histologically screened for the presence of pneumonitis and examined for pinworm infection. Newly arrived goats were examined, deloused, dewormed and routine blood work consisting of a CBC and 16 parameter biochemical screen was performed.

Table 2 summarizes animals procured, housed and cared for during FY 79.

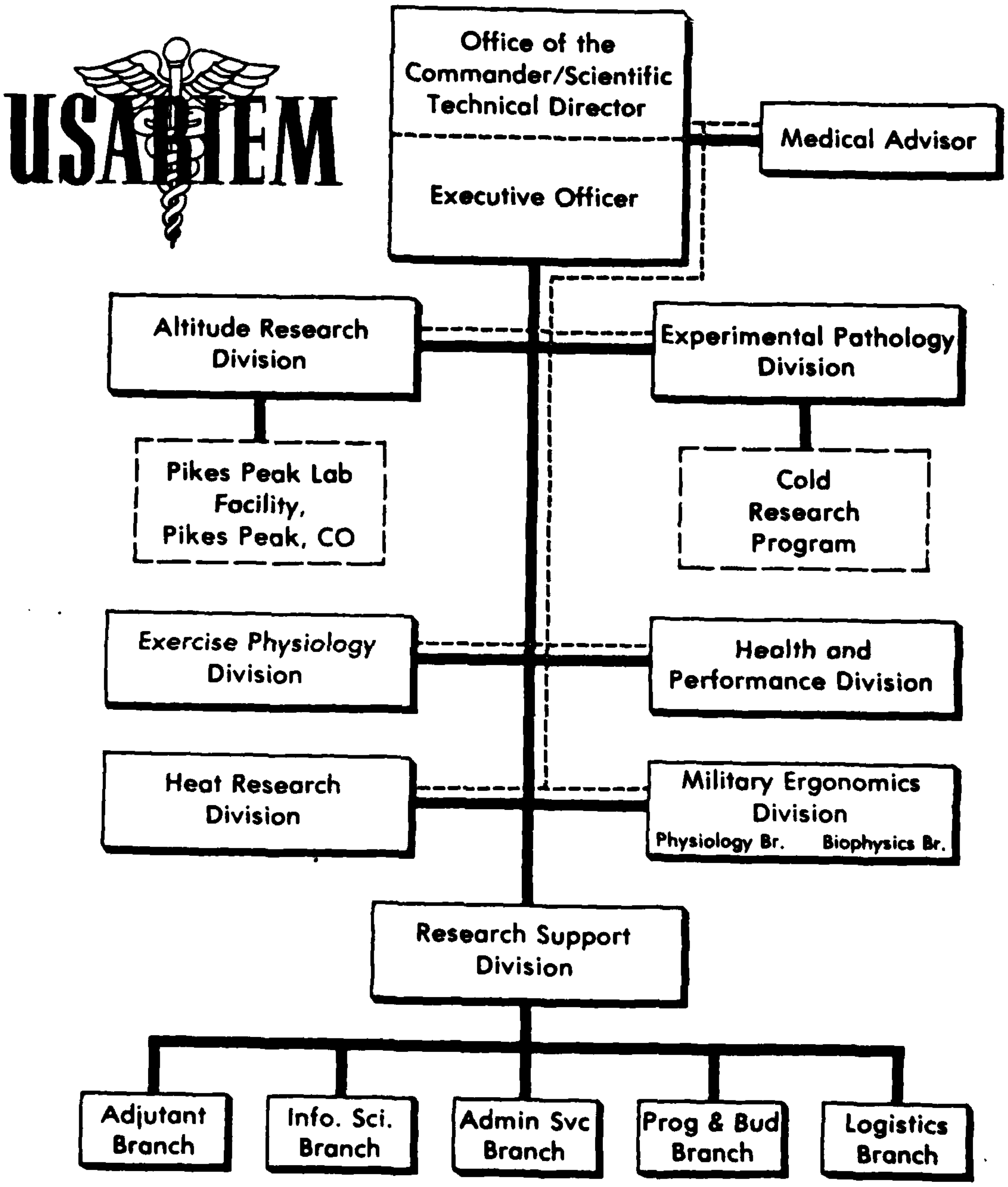
TABLE 2

Animals Cared For During FY 79

	Average Daily	Annual
Goats	13	15
Dogs	12	20
Rabbits	20	20
Mice	25	25
Rats	400	1243

APPENDIX A

US ARMY RESEARCH INSTITUTE OF ENVIRONMENTAL MEDICINE
NATICK, MASSACHUSETTS 01760



APPROVAL: Harry G Dangerfield, MD

HARRY G. DANGERFIELD, M. D.
Colonel, MC
Commanding

DATE: 6 June 1978

COMMAND ————
TECHNICAL COORDINATION -------

APPENDIX B

PUBLICATIONS

Boyd, A. E. III, G. Angoff, A. Long and M. Mager. L-DOPA absorption and the pituitary-hypothalamic axis, evidence for shortloop control of growth hormone secretion. J. Clin. Endocrin. and Metab. 47:1341-1347, 1978.

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APPENDIX C

ABSTRACTS AND PRESENTATIONS

Avellini, B. A., E. Kamon and J. T. Krajewski. Physiological responses of fit men and women before and after acclimation to humid heat. American College of Sports Medicine Annual Meeting and Pan Pacific Conference, Honolulu, HI, 23-26 May 1979. Med. Sci. Sports 11:101, 1979.

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Banderet, L. E. and J. W. Stokes. Laboratory simulation studies using actual Army fire direction center teams. The Technical Cooperation Program (TTCP) Action Group UAG-4, USAF School of Aerospace Medicine, Dec '78, San Antonio, TX. Abstract in TTCP UAG-4 Report, Performance Limits in Extended Military Operations, Appendix 4, May 1979.

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Banderet, L. E. Group and individual FDC performance and nontask behavioral assessment. Part of a symposium at the Annual Meeting of the American Psychological Association, New York, NY, 4 September 1979.

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Francesconi, R. P. Sustained operations and sleep deprivation: effects on some stress indices. Part of a symposium at the Annual Meeting of the American Psychological Association, New York, NY, 4 September 1979.

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Vogel, J. A. Fitness and work capacity of women: Military Services Symposium, Am. College of Sports Medicine, Honolulu, HI, 25 May 1979.

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Young, Andrew J., J. E. Wright, J. J. Knapik, J. Scelza and A. Cymerman. The effect of altitude exposure on skeletal muscle strength in man. Annual Meeting of the American College of Sports Medicine and Pan Pacific Conference, Honolulu, HI, 23-26 May 1979. Med. Sci. Sports 11:88, 1979.

APPENDIX D

CONSULTATIONS

Requesting Individual/Agency	Subject	Month
Jerome A. Dempsey, Ph.D. Department of Preventive Medicine University of Wisconsin Madison, WI	Special problems of athletic endeavors at high altitude	October
Charles S. Houston, M.D., Ph.D. Department of Epidemiology and Environmental Health University of Vermont Burlington, VT	Advice on scientific program for International Hypoxia Symposium	October
Kathy Jovah Madamoiselle Magazine New York, NY	Article on cold weather	October
Barbara Raisbeck, Ph.D. 40 Bloomfield Street Newton, MA	Altitude research mission and program	October
Joanne Sedor Congressional Office of Technology Washington, DC	Statistics on residential energy conservation study correlating impact of poor housing on hypothermia	October
TRADOC Combined Arms Test Activity Ft. Hood, TX	Environmental factors in the DRS field artillery battalion test at Ft. Hood, July 1978.	October
Curt Allen DCIEM Ontario, Canada	Muscle strength methodology	November
CPT Britten MP School Ft. McClellan, AL	Physical training	November
Division Surgeon and DIVARTY Chemical Officer 1st CAV DIV Ft. Hood, TX	Safe performance limits for troops volunteering to compete in a "pentathalon" of PT tests wearing the chemical protective mask	November
Fred Dyer, Ph.D. ARI Ft. Benning, GA	Research proposal	November

CPT Jared Jobe HQ USA CDEC Ft. Ord, CA	Problems in the heat	November
Paul Langner Boston Globe Boston, MA	Hypothermia	November
MAJ Bruce Leibrecht, MSC, Ph.D. Operations Division HQ, USAMRDC, Ft. Detrick Frederick, MD	Altitude research mission and program	November
SFC John Sexton Ft. Devens, MA	Winter camping	November
H. Wright Institute of Human Performance	Body composition	November
Joseph Yang, M.D. Principal Deputy f/Army Asst. Secretary f/R&D Department of the Army Washington, DC	Altitude research mission and program	November
LTG Robert J. Baer Deputy Commanding General for Materiel Development DARCOM Washington, DC	Information and demonstration of AGA thermovision camera	December
MAJ Holly HQDA-ODCSPER The Pentagon Washington, DC	Contract review	December
LT Cdr D. A. Ingrum, USN US Navy Amphibious Base Coronado, CA	Methods of solving for heat losses from men in wet diving suits. Windchill on men emerging from water	December
M. Manjoo University of Durburn South Africa	Problems in the heat	December
M. Mann Cambridge YWCA Cambridge, MA	Physiological instrumentation	December
LTC Roger Robie Comptroller HQ, USAMRDC, Ft. Detrick Frederick, MD	Altitude research mission and program	December

LT B. Senchy USAF Hospital Altus AFB, OK	Minimum temperatures for plane washers dressed in foul weather gear. winds of 30 knots	December
Kathy Engelbert School of Health Department of Nutrition Loma Linda University Loma Linda, CA	Nutritional aspects of altitude acclimatization	January
Federal Community Services Agency Washington, DC	Emergency energy conservation, accidental hypothermia and programs to provide supplementary heating fuel allowances to welfare recipients	January
Clarence Hartman ARRADCOM Dover, NJ	Load carriage	January
D. Lichtenstein Australian Forces Food Sc. Establishment Scottsdale, Tasmania	On-line $\dot{V}O_2$ methodology	January
David M. Millsaps, M.D. Charlotte Memorial Hospital Charlotte, NC	First-aid requirements for mountain climbers	January
CPT Jefferson B. Prather School of Aerospace Medicine Brooks AFB, TX	Film - Operations in a toxic environment	January
Preventive Medicine Activity Letterman Army Medical Center San Francisco, CA	Heat injury prevention cards for distribution to reserve units - San Joachim Valley	January
TRADOC Combined Arms Test Activity Ft. Hood, TX	Drafting the Outline Test Plan (OTP) for FT 444 (Field Artillery Crew Test), at TCATA	January
TRADOC Combined Arms Test Activity Ft. Hood, TX	Discussion with the Technical Cooperation Program (TCP) Action Group U-4 on the proposed design for TCATA field test of howitzer crew capabilities in sustained (8-day) high intensity action.	January

Marion Wells American Physical Fitness Institute 824 Morrata Drive West Los Angeles, CA	Running in the cold	January
Colonel Wheelan Army Public Affairs Washington, DC	Calories for cold weather	January
MAJ Peggy Wheeler USA Environmental Hygiene Agency Aberdeen Proving Ground, MD	Cold discomfort complaints at 65°F air temperature	January
LTC Addy Artillery School Ft. Sill, OK	Occupational standards	February
Robert Fenichel, M.D. 828 Sixth Street Santa Monica, CA	The influence of fitness on performance at high altitude	February
LTC Grosbeck USDAO Nigeria	Physical training	February
Dr. Bryan D. Hubble Meadowbrook Medical Building St. Louis Park, MN	Estimation of heat loss under varying environmental conditions	February
Herbert N. Hultgren, M.D. Stanford Medical School Stanford, CA	The effect of furosemide treatment on the development of acute mountain sickness	February
Lt. Massengill 46 Eng Bn Ft. Rucker, AL	Physical training	February
9th Infantry Division Surgeon Ft. Lewis, WA	Physical training	February
Arnold Sookne Burlington Industries Greensboro, NC	Thermal comfort	February
Captain Tate Army Ordnance Center & School Aberdeen Proving Ground Aberdeen, MD	Doctrine on protection for continuous wear with Nomex and overgarment; AR guidelines for ambient environments	February

Hans K. Akerblom The Nordic Council for Arctic Medical Research Finland	Arctic medicine	March
MAJ Paul L. Caron Food Engineering Laboratory USANARADCOM Natick, MA	Nutrition and altitude acclimatization	March
COL Martin Chipman, MC US Army Biomedical Laboratory Aberdeen Proving Ground Aberdeen, MD	Altitude research program and discussed possible collaborative research on the effect of anticholinesterase on performance at high altitude	March
COL Martin Chipman, MC US Army Biomedical Laboratory Aberdeen Proving Ground Aberdeen, MD	Performance and biomedical evaluation of artillery FDC teams in a laboratory simulation: possible application for testing behavioral side effects of prophylactic and therapeutic defenses against chemical warfare agents.	March
Jennifer Cook Self Magazine New York, NY	Comfort in clothing	March
Elliot Danforth, Ph.D. University of Vermont Burlington, VT	Total body water in man	March
MG Kenneth R. Dirks, M.D. Superintendent, Academy of Health Sciences Ft. Sam Houston, TX	Altitude research mission and program	March
Robert L. Henn W. L. Gore & Assoc., Inc. Elkton, MD	Gortex	March
MAJ W. E. Lindsay Ft. Leavenworth, KS	Survival items	March
MAJ Sam Murphey FACT Test Officer TCATA Ft. Hood, TX	Motivation and Morale Factors in the Field Artillery Crew Test (Memo by L.E. Banderet & J. W. Stokes, dtd 1 June 1979)	March-June

John Nielsen Manager, Operations Improvement CONRAIL Philadelphia, PA	Effects of external environment on productivity	March
Dr. W. Rutenberg University of Illinois Medical School Urbana, IL	Metabolic instrumentation	March
Margorie Salwin The Pentagon Washington, DC	Water requirements	March
Frank Toth Walter Reed Army Institute of Research Washington, DC	Technical advisor in preparing cold injury movie	March
2/75 Ranger Battalion Ft. Lewis, WA	Physical training	March
USA CD Activity Alaska	Foam pads vs. air mats	March
US Army Infantry School Ft. Benning, GA	Footwear and training	March
US Forces Surgeons Command Ft. McPherson Atlanta, GA	Stress testing	March
MAJ D. Wiemers MEDDAC Ft. Carson, CO	Jet-lag	March
P. C. Agawal Government of India Ministry of Defence New Delhi, India	Anthropometry (hands) Indian Armed Forces	April
Prof. Stanley Backer M.I.T. Cambridge, MA	Anthropometric dimensions	April
Dr. John R. Claybaugh Clinical Investigation Service Tripler Army Medical Center Honolulu, HI	Design of high-altitude field study	April
Eliot Danforth, M.D. Department of Medicine University of Vermont Burlington, VT	Calorimetry - animal studies	April

Doctrine Team, Combat Developments Directorate US Army Field Artillery School Ft. Sill, OK	Proposed specifications, structure & SOP for the scenario of FT 444, the Field Artillery Crew test	April-July
Chief, Doctrine Team Combat Developments Directorate US Army Field Artillery School Ft. Sill, OK	Environmental medical and fatigue factors in field artillery personnel and weapons systems	April
Dr. John A. Feagin, CDR, MEDDAC Dr. Leigh F. Wheeler USMA West Point, NY	Collaborative interests	April
LTC Clarence Givens Hanscom AFB Bedford, MA	Energy conservation and human comfort	April
CPT Dan Headly CPT James Ramano Experimental Medical Division Edgewood, MD	Experimental design considerations in evaluating effects of anti-chemical warfare prophylactic drugs on military performance	April
Donald D. Heistad, M.D. Department of Internal Medicine University of Iowa College of Medicine Iowa City, IA	Local and reflex mechanisms of cardiovascular control during hypoxia	April
MAJ Roger P. Hula, II MRDC Headquarters Ft. Detrick Frederick, MD	Cold weather operations-heating mechanisms - CVC crew clothing ensembles	April
CPT Jared Jobe HQ USA CDEC Ft. Ord, CA	Heat regulation - cutoff limits	April
CPT Milton Lapp Corning, NY	Extreme cold conditions	April
Richard Omori Medical Intelligence Agency Ft. Detrick Frederick, MD	Frostbite testing device Japanese developed in Manchuria, WWII (Kata thermometer)	April
H. F. Pauley Tech Assoc.-Industrial Hygiene Duke Power Company Charlotte, NC	Working in impermeable clothing ensembles (nuclear power plant operations)	April

LTC Rengstorff, MSC Designate Director of Experimental Medicine Division Biomedical Laboratory Edgewood, MD	Potential application of FDC team simulation studies to testing operational impact of chemical warfare prophylactic agents	April
Majorie Salwin The Pentagon Washington, DC	Water discipline and consumption; questions regarding Dr. Adolph's desert research	April
Training Developments Director, USAFAS Ft. Sill, OK and Div. of Biorrheology, LAIR Presidio, San Francisco, CA	Safety limits and training for laser range finders and ground laser-locators designators	April-May
CPT Tupa Chemical Officer, 9th Infantry Division Ft. Lewis, WA	Guidance on WBGT limits for activity in CBR mask plus overgarment	April
MAJ Vorpahl OTSG Washington, DC	Mobile computer van crew compartment temperatures	April
MAJ Wood OTSG Washington, DC	Ground crew (USAF) performance guidance for CW protective clothing; comfort attainable under Dept. of Energy conservation guidelines.	April
Ellen Ahrbeck Coates & Clark, Inc. Stamford, CT	Inquiry on energy conservation guidelines and effects on comfort	May
Dr. N. Bethea Texas Tech University Lubbock, TX	Occupational standards	May
John Blackwood Frelen Corporation Lowell, MA	Guidance on closed cell foam polyethylene camping pad evaluations	May
Patricia Ezekiel Carolina Wilderness Institute Greensborough, NC	Insulation values of cold weather and indoor clothing items; requirements for comfort at low indoor temperatures	May

Dr. Gerlach Stanford Research Institute Stanford, CA	Comfort-cold acclimatization, dynamic control of environments	May
Dr. C. K. Giam Singapore Sports Council Singapore, Malasia	Physical performance limits	May
William G. Hildebrand The North Face Company 1234 5th Street Berkeley, CA	Reflective materials	May
Max Lippitt Naval Coastal Systems Center Panama City, FL	Potential benefits & heat stress problems associated with use of vapor barrier layers next to the skin in "dry suit" divers clothing	May
James Lyddy & Larry Richardson Arthur D. Little Co. Cambridge, MA	Design requirements for underwater copper manikin being procured under contract by Navy Clothing & Textile Research Facility, Natick, MA	May
Dr. S. Malmstrom Swedish Defence Ministry Sweden	Fitness assessment	May
Joseph B. Murphy, COL (Ret) Science Applications, Inc. McLean, MD	Effects of sleep deprivation and battle stress on Army crew and unit organizational effectiveness for use in computer simulation model for DCSOPS	May
Dennis Metz AMSAA Aberdeen Proving Ground, MD	Physiological stress under various environmental conditions while wearing the US chemical protective overgarment in "open" and "closed" suit configurations	May
M. Morris N. White H. Prato University of California Davis, CA	Design requirements of warm-up suits for comfort of Olympic athletes in 1980 Olympics, Moscow	May

MAJ Sherman Preventive Medicine Activity Ft. Riley MEDDAC Ft. Riley, KS	Comparison of various WBGT kits	May
Richard Tell Environmental Protection Agency Las Vegas, NV	Protection against heat stress for microwave radiation	May
Penny Wong Self Magazine New York, NY	Clothing and comfort	May
Ellen Ahrbeck Coats & Clark, Inc. Stamford, CT	Wind chill chart	June
Ronald Benton Honeywell, Inc. Minneapolis, MN	Dew point hygrometer	June
Jill Cohen ABC Newsweek New York, NY	Thermostat settings; climatic chamber studies	June
Dr. Ching Aeromedical Activity Ft. Rucker, AL	Wind chill charts	June
Jennifer Cook Self Magazine New York, NY	Water bath temperatures and comfort	June
LTC Harry E. Davis Ft. Reilly, KS	Salt replacement with heat exhaustion	June
CPT Larry Dean, USN Naval Medial Submarine Research Laboratory Groton, CT	Cold weather epidemiology	June
Mark Ferravalle ABC Radio Detroit, MI	Thermostat settings, thermal comfort, level of clothing worn. (Live radio interview)	June
George Getschow Wall Street Journal Pittsburgh, PA	Indoor air pollution	June

Dr. C. K. Giam Sports Medicine & Research Center National Stadium, Kallang Republic of Singapore	Incipient physical exhaustion	June
Francis J. Haddy, M.D., Ph.D. Chairman, Dept. of Physiology Uniformed Services University of the Health Sciences Bethesda, MD	Pathogenesis of high altitude pulmonary edema	June
Walter H. Inge, Ph.D. Sargent College of Allied Health Professions Boston University Boston, MA	Nutritional aspects of high-altitude acclimatization	June
Kansas City Times Kansas City, MO	Federal temperature controls. NY Times wire pick up	June
SGT M. Kenney Ft. Devens, MA	Scuba diving, heat, dehydration	June
COL Stanley C. Knapp USA Aeromedical Research Laboratory Ft. Rucker, AL	Examination questions for Part II (Aerospace Medicine) of the American Board of Preventive Medicine's examination for certifying physicians	June
Cdr Leffingwell, M.D. Industry Wide Studies Branch NIOSH Cincinnati, OH	Possible biomedical hazards of positive air ions	June
Dr. Janet W. MacArthur Dept. of Obstetrics and Gynecology Mass. General Hospital Boston, MA	Effects of exercise on menstrual functions	June
Dr. John Magel Dr. William McArdle Queens College, NY	Collaborative study on water immersion	June
G. McDermott US Secret Service Washington, DC	Stress testing	June

Military Academy Personnel USMA West Point, NY	Collaborative research ideas	June
Naval Submarine Medical Research Laboratory Groton, CT	Discussion of areas of mutual interest	June
New York Times New York, NY	Federal temperature guidelines	June
LT Norris Ft. Sill, OK	Limits of exposure in dry and humid sauna baths	June
Mario Paz-Zamora, M.D. Director, Dept. of Bioenergetics Bolivian Institute of Altitude Biology La Paz, BOLIVIA	Medical and performance disabilities at high altitude	June
LT Norris Ft. Sill, OK	Safety in post recreational saunas	June
COL H. Lomax Roberts, British Liaison Officer to The Surgeon General LCOL John A. Macdougall, Canadian Liaison Officer to The Surgeon General Washington, DC	Areas of mutual interest	June
Rick Ruiz ABC Newsweek New York, NY	Energy conservation, thermostat settings, clothing and comfort	June
The Sun News Las Cruces, NM	Federal temperature controls	June
COL Spear Academy of Health Sciences Ft. Sam Houston, TX	Cold acclimatization doctrine	June
Wayne Stevens Radio Station CKWW Windsor, Ontario, Canada	Problems in the heat	June
T. Anderson US National Park Service Washington, DC	Occupational standards	July

E. T. Angelakos, M.D., Ph.D. Dept. of Physiology & Biophysics Hahnemann Medical College & Hospital Philadelphia, PA	Drug testing in a hypoxic animal model	July
Heather Birchall MacLean's Magazine Canada	Male - female differences in the cold	July
Janet Bodnar Changing Times Magazine Washington, DC	Clo insulation values	July
Boston Phoenix Boston, MA	Summer comfort	July
Rita Christopher McLeans Magazine New York, NY	Guidelines on thermostat settings	July
LTC Walton W. Curl, MC Keller Army Hospital US Military Academy West Point, NY	Altitude research mission and program	July
Mike L. Czeczot South Middlesex News	Interviews: 1. Heat up - so slow down 2. 78°F thermostat settings	July
Paul DeWitt Sunbeam Corporation	Comfort in industry	July
Director, Training Developments Directorate, USAFAS Ft. Sill, OK	Cost-ineffectiveness of Gatorade as the required beverage for basic trainees at Ft. Sill, OK	July
Frank N. Dukes-Dubos, M.C. National Institute for Occupational Safety and Health Cincinnati, OH	Safety criteria through models for industry	July
Dr. Charles Eagan Defense Research Establishment Ottawa, Canada	Comparison test - Gortex rainsuit vs. standard Canadian Forces suit	July
CPT Fercheck MAJ Donovan Evaluation of Women in the Army (EWITA) II Ft. Benjamin Harrison, IN	Methodology for assessing how many women can be assigned to different types of units	July

MAJ Forest Follett Umatilla Depot Activity Health Service Clinic Hermiston, OR	Modifying standards for wear of NBC clothing by older men (50+)	July
LT Gardner White Sands Missile Range White Sands, NM	Recovery time after exposures to cold chambers	July
Sue Costill Glamour Magazine New York, NY	Dressing for cooler temperatures	July
Monica Glumm Human Engineering Laboratory Aberdeen Proving Ground, MD	Techniques for determining air infiltration	July
Nancy Griffin Time Magazine New York, NY	Human response to thermal environment	July
Robert Haney Metromedia Washington, DC	Effects of 78°F thermostat setting	July
Human Resource Research Office Ft. Hood, TX	MOS standards	July
CPT James Jaeger WRAIR, Washington, DC and MAJ Whisenant Field Artilllery Board Ft. Sill, OK	Implications for gun crew safety and hearing protection of the planned test of an extended range munition for the self-propelled 155 mm howitzer	July-August
Jean Kalb Boston Herald Boston, MA	Effects of 78°F thermostat set point	July
Richard Kirkland Radio Station WITS Boston, MA	Hot, humid weather and crimes of violence	July
Sukhamay Lahiri, Ph.D. Hospital of the University of Pennsylvania Philadelphia, PA	Techniques of cisternal and ventricular cannulation and perfusion in goats	July
CPT Gordon Lidford Academy Health Sciences Ft. Sam Houston, TX	Salt tablets in the heat	July

COL John D. Marshall, CDR LAIR San Francisco, CA	Areas of mutual interest	July
Mitchell Chemical Systems Laboratory Aberdeen Proving Ground, MD	Military functions and metabolic rates	July
John Muller MacLean, VA	FEO guidelines	July
CPT Nidel Chemical Systems Laboratory Aberdeen Proving Ground, MD	Chemical protective clothing	July
Alexis Parks Department of Energy Washington, DC	Federal temperature control guidelines	July
Playboy Magazine Chicago, IL	Cold weather clothing	July
Dr. Jerry D. Ramsey Texas Tech University Lubbock, TX	Figure - Cooling power of wind on exposed flesh expressed as an equivalent temperature	July
Gini Sampson Endicott Publishing Corp. North Carolina	Factors affecting comfort	July
Ronald Schultz Pinella Courthouse 315 Court Street Clearwater, FL	Requested information relating changes in subjective comfort to air velocity in hot environments	July
Robert Segal NBC Washington, DC	Re: Prime Time TV program $78^{o}F$ - $65^{o}F$ Federal	July
Margory Sherman Lawrence Eagle Tribune Lawrence, MA	Latest research explains why the body protests too much heat	July
Silverman Los Angeles Examiner Los Angeles, CA	Human heat balance, clothing and comfort	July
John Stark Science Applications, Inc. McLean, VA	Heat casualty model	July

US Army Field Artillery School Ft. Sill, OK	Symposium on the psychological suppressive effects of artillery fire on military performance, Ft. Sill, OK	July
Leo Balzano Pinkerton's, Inc. New York, NY	Cold weather information	August
Anne Beaton The Boston Herald American Boston, MA	Effect of 78°F thermostat setting	August
LTC John Bell DARCOM Surgeon's Office Alexandria, VA	Altitude research mission and program	August
George Crowley Northern Electric Company Chicago, IL	Role of clothing in extending human thermal comfort	August
William N. Dasheff Dasheff and Dearborn New York, NY	Physiological effects of clothing on man and clothing design	August
DOD Cardiopulmonary Research Committee Aberdeen Proving Ground Aberdeen, MD	Medical aspects of chemical defense	August
Major Evans HQ MAC/XPQA Scott AFB, IL	Air transport of troops to the FEBA as opposed to foot marches	August
P. O. Fanger, Ph.D. Technical University of Denmark Lyngby, Denmark	Manikin measurement of clothing ensembles	August
LT Sandra Gatling Ft. Stewart, GA	Cold weather training assistance	August
Godwin Kelly AFB, TX	Engineering of life support systems; Arctic survival sleeping bags	August
Harry Guy Weyerhauser Company Tacoma, WA	Heat stress on men working in lumber drying kilns	August
Fred W. Hensen Textize Greenville, SC	The effects of environmental conditions on comfort and working efficiency	August

William Buckley Columbia-Presbyterian Medical Center and Scott Broadcast Services, Inc. New York, NY	Perception of effort as a function of activity experience (Interview)	August
Richard Kirkland Radio Station WITS Boston, MA	Problems people will have in their homes this winter with hypothermia	August
Steven Lang Sportstyle Magazine New York, NY	Copper man	August
Cdr Leffingwell, M.D. Industry Wide Studies Branch NIOSH Cincinnati, OH	Evaluation of long term neuropsychological effects in lead auto battery factory workers (consultant for review of proposed NIOSH research contract)	August
Edwin C. McCullough, M.D. Mayo Clinic Rochester, MN	Info required on climatic chamber specs - humidity/temperature controls	August
Marion Miller General Monitors, Inc. California	Load carriage	August
Winston Morris First Magnolia Federal Savings and Loan Jackson, MI	Thermostat settings - building restrictions	August
New Jersey Solar Action Trenton, NJ	Comfort in exterior and interior climatic conditions	August
COL R. Ross Preventive Medicine USA MEDDAC Ft. Jackson, SC	Botsball - defining heat stress	August
William Ruxton National Tool, Die and Precision Machining Assoc. Washington, DC	Tactile sensitivity in the cold	August
Diane Stearns Radio Station WEEI Boston, MA	Thermal comfort segments	August

Camilo J. Vergara State of New Jersey Department of Energy Newark, NJ	Clothing and human thermal comfort	August
LTC Charles Clark, M.D. VICENZA MEDDAC APO, New York, NY	Information on cold weather preventive medicine	September
Dr. Ruth Davis, Deputy Under-secretary of Defense for Research and Engineering Washington, DC	Areas of mutual interest	September
Donald Dunn Business Week Magazine New York, NY	Cold winter (65°F) office clothing	September
LTC Charles Clark, M.D. VICENZA MEDDAC APO, New York, NY	Cold injuries at high terrestrial elevations	September
Dr. Frode Fonnum Norwegian Defence Research Establishment Kjeller, Norway	Cold weather program here at USARIEM	September
Harper's Bazaar Magazine New York, NY	Effects of cold temperatures on comfort	September
Colonel Lescoe TRADOC Ft. Monroe, VA	Heat stress	September
Dr. R. Smith General Motors Corp Detroit, MI	Women in traditional male jobs	September
Colonel Varpahl Office of The Surgeon General Washington, DC	Minimum temperature for health in occupied spaces	September

APPENDIX E

BRIEFINGS

Dangerfield, H. G. What military services are doing to establish gender-free physical standards and measures for the various specialties/ratings. DACOWITS (Defense Advisory Committee on Women in the Services) Semiannual Meeting, Biltmore Hotel, New York, NY, 29-30 October 1978.

Dangerfield, H. G. Fitness research project. Deputy Chief of Staff. Pentagon, Washington, DC, 10-11 December 1978.

Dangerfield, H. G. MOS study requirements. FORSCOM, Atlanta, GA, 21 March 1979.

Dangerfield, H. G. Physical standards. Assistant Secretary of the Army. Washington, DC, 9 July 1979.

Dangerfield, H. G. *In process review (IPR) on physical fitness training project*, Major General Smith, Ft. Benning, GA, 8 August 1979.

Dangerfield, H. G. Problem definition meeting in heat stress in military operations in 1980-1990 timeframe. Ft. Monroe, VA, 27 September 1979.

Devine, J. A. Hypobaric chamber utilization at USARIEM. Aviation Physiological Training Unit, Pease AFB, Portsmouth, NH, 9 January 1979.

Goldman, R. F. I. Comfort; II. The military difference; III. Human heat balance; IV. Adequate forcing functions; V. Climatic chamber studies of clothing; VI. The four key thermal environmental factors; VII. Human tolerance; VIII. Prediction of physiologic responses; IX. History of CBW; X. Past research. NAS-NRC-NAE CBR Panel Briefing, NARADCOM, Natick, MA, 14 June 1979.

Hamlet, M. P. Cold weather preventive medicine, 4th Marine Air Wing Commanding Officer's Conference, New Orleans, LA, 1-4 October 1978.

Hamlet, M. P. Cold weather preventive medicine. Troops and command staff, Ft. Bragg, NC, 10-13 October 1978.

Hamlet, M. P. Cold weather preventive medicine. Troops, medics and command staff, Ft. Riley, KS, 6-9 November 1978.

Hamlet, M. P. Cold weather preventive medicine. Army Security Agency, Ft. Devens, MA, 20 November 1978.

Hamlet, M. P. Cold weather preventive medicine. Medical staff and troops going to Alaska, 101st Air Mobile Div., Ft. Campbell, KY, 30 November-1 December 1978.

Hamlet, M. P. Cold weather preventive medicine. Cutler Army Hospital Staff, Ft. Devens, MA, 8 December 1978.

Hamlet, M. P. Cold weather preventive medicine. Troops, physicians, and command staff, Pickle Meadows Marchine Corps Training Camp, Bridgeport, CA, Camp Pendleton, CA & Ft. Benning, GA, 8-15 December 1978.

Hamlet, M. P. Cold weather preventive medicine. 25th Inf Div, Schofield Barracks, HI, 6-13 January 1979.

Hamlet, M. P. Cold weather preventive medicine. Medical and command staff, Ft. Polk, LA, 24-26 January 1979.

Hamlet, M. P. Assisted the Commanding General of the 25th Inf Div in early deployment for cold weather exercise entitled, "Free Spirit", Seoul, Korea, 24 February-8 March 1979.

Hamlet, M. P. Prevention and treatment of cold weather injuries, USMCR, Worcester, MA, 10 & 11 February 1979.

Hamlet, M. P. Cold weather. Flight Surgeon's course on "Temperature Extremes", USAAMED Center, Ft. Rucker, AL, 12 & 13 March 1979.

Hamlet, M. P. Cold weather preventive medicine. Conference on Medical Support in Cold Weather Operations, Academy of Health Sciences, Ft. Sam Houston, TX, 4-6 June 1979.

Hamlet, M. P. Cold weather preventive medicine. Cold Weather Medicine Conference, San Diego, CA, 6-9 August 1979.

Hamlet, M. P. Cold weather preventive medicine. 10th Special Forces, Ft. Devens, MA, 28 September 1979.

Hubbard, R. W. An analysis of current doctrine in use (USA vs IDF) for the prevention and treatment of heat casualties resulting from operations in the heat. Commanders Conference, 4th MAW/MARTC, New Orleans, LA, 1-4 October 1978.

Hubbard, R. W., M. Hamlet and M. Mager. Temperature extremes (heat and cold). Flight Surgeon's Conference, USAAMED Center, Ft. Rucker, AL, 12-13 March 1979.

Hubbard, R. W. and M. Mager. Hot weather operations. 3rd Bn., 47th Infantry and 75th Ranger Bn., Ft. Lewis, WA, 28-30 March 1979.

Hubbard, R. W. and M. Mager. Hot weather operations. 9th Infantry Division, Ft. Lewis, WA, 28-30 March 1979.

Hubbard, R. W. Problems in the heat. 36th Medical Batallion, Ft. Devens, MA, 17 April 1979.

Hubbard, R. W. and M. Mager. Problems in the heat. 3rd Battalion, 10th Special Forces, Ft. Devens, MA, 31 May 1979.

Hubbard, R. W. Problems in the heat. Physicians at MEDDAC, Cutler Army Hospital, Ft. Devens, MA, 15 June 1979.

Hubbard, R. W. and M. Hamlet. Temperature extremes (heat and cold). Flight Surgeon's Course, USAAMED Center, Ft. Rucker, AL, 12-13 September 1979.

Hubbard, R. W. and M. Mager. Etiology, prevention, treatment and diagnosis of problems in the heat. 804th Hospital Center, Hanscom AFB, MA, 29 September 1979.

Maher, J. T. Physiological effects of high altitude. Physiological Training Unit, Peterson AFB, Colorado Springs, CO, 29 August 1979.

Stokes, J. W. and L. E. Banderet. Environmental stress and fatigue factors in the test of the DRS Field Artillery Battalion in August 1978 at Fort Hood. Asst. Commandant, USAFAS, Ft. Sill, OK, 3 October 1978.

Vogel, J. A. Physical training program revision IPR. HQ-Army Training and Doctrine Command (MG Hixon) and DA-DCSOPS (MG Smith), Ft. Monroe, VA, 24 January 1979.

Vogel, J. A. Physical training program revision IPR. HQ Army Training and Doctrine Command (BG H. G. Crowell), Ft. Monroe, VA, 13 February 1979.

Vogel, J. A. Physical training program revision IPR. HQ-Army Training and Doctrine Command (MG R. Hixon), Ft. Monroe, VA, 27 February 1979.

Vogel, J. A. Physical training program requirements. HQ-FORSCOM, DCSOPS (MG EcEnry), Ft. McPherson, Atlanta, GA, 19 March 1979

Vogel, J. A. Physical training program requirements. HQ-USAMRDC (COL L. G. Jones), Ft. Detrick, MD, 22 March 1979.

Vogel, J. A. Physical training program requirements. HQ-DASG (MG H. Mendez), Pentagon, Washington, DC, 4 April 1979.

Vogel, J. A. Physical training program requirements. HQ-DCSPER (MG J. G. Boatner), Pentagon, Washington, DC, 5 April 1979.

Vogel, J. A. AFEES Fitness Standards IPR. HQDA-DCSPER (LTG R. G. Yerks), Pentagon, Washington, DC, 9 July 1979.

Vogel, J. A. Physical training program revision IPR. Asst. Sec. Army for Manpower and Reserve Affairs (Mr. R. Nelson), Pentagon, Washington, DC, 10 July 1979.

Vogel, J. A. Physical training program revision IPR. HQ, DA-ODCSOPS (MG J. C. Smith), Ft. Benning, GA, 8 August 1979.

APPENDIX F

LECTURES

Burse, R. L. Human thermoregulation. Boston University Sargent College of Allied Health Professions, Boston, MA, 19 and 21 March 1979.

Cymerman, A. Pulmonary ventilation at sea level and high altitude. Boston University Sargent College of Allied Health Professions, Boston, MA, 19 March 1979.

Cymerman, A. Subclinical pulmonary edema at high altitude. Pulmonary Function Unit, Massachusetts General Hospital, Boston, MA, 4 June 1979.

Dangerfield, H. G. Community Health and Environmental Sciences. Academy of Health Sciences, Ft. Sam Houston, TX, 5-7 November 1978.

Dangerfield, H. G. Research in Environmental Stress. Academy of Health Sciences, Ft. Sam Houston, TX, 10 May 1979.

Fencl, V. Acid-base balance. Department of Anesthesia, Children's Hospital Medical Center, Boston, MA, 21 November 1978.

Fencl, V. Regulation of respiration at high altitude. University of Pennsylvania, Philadelphia, PA, 23 January 1979.

Fencl, V. Regulation of respiration at high altitude. Department of Physiology and Pharmacology, University of Massachusetts, Worcester, MA, 2 March 1979.

Fencl, V. Cerebral fluids in respiratory adaptation to high altitude. Boston Gas Club, Boston, MA, 19 March 1979.

Fencl, V. Effect of body temperature on acid-base balance. Division of Pulmonary Medicine, Boston University School of Medicine, Boston, MA, April 1979.

Fencl, V. Regulation of respiration at high altitude. Division of Pulmonary Medicine, Case Western Reserve University School of Medicine, Cleveland, OH, 18 May 1979.

Goldman, R. F. Thermal environmental stress. Noll Laboratory for Human Performance Research, Penssylvania State University, University Park, PA, 25 January 1979.

Goldman, R. F. Functional clothing design. Visiting Scholar Lecture Series, University of Rhode Island, Kingston, RI, 20 March 1979.

Goldman, R. F. Survival-Medical Environment. USAAVNC/USANARADCOM Tri-Service Conference on Survival Kits and Vests, Natick, MA, 20-21 March 1979.

Goldman, R. F. Body composition and its alteration by diet and exercise. American Dietetic Association, Sheraton-Tara Hotel, Framingham, MA, 11 April 1979.

Goldman, R. F. Military applied physiology. Uniformed Services University of The Health Sciences, Bethesda, MD, 22 May 1979.

Goldman, R. F. Military applied physiology. Uniformed Services University of The Health Sciences, Bethesda, MD 29 May 1979.

Goldman, R. F. (1) Body composition, assessment: analysis of energy balance; (2) Body typing; (3) obesity: analysis of composition of weight changes. Applied Nutritional Assessment Workshop, Boston University, Boston, MA, 6 June 1979.

Goldman, R. F. Obesity and endocrine control. National Institutes of Health, Phoenix, AZ, 15 June 1979.

Goldman, R. R. The heat production of the soldier and his work limitations; Thermal environmental stress - heat and cold limitations of military performance. WRAIR sponsored course on Tropical Medicine, Washington, DC, 22 August 1979.

Goldman, R. F. Heat stress associated with NBC protective clothing. Chemical Systems Laboratory, Aberdeen Proving Ground, MD, 5 September 1979.

Goldman, R. F. Work stress and protective clothing. Occupational Medicine Course, Aberdeen Proving Ground, MD, 27 September 1979.

Hamlet, M. P. Prevention and treatment of cold injuries. ADK-AMC Winter Mountaineering School, Littleton, NH, 27 December 1978.

Hamlet, M. P. Frostbite and hypothermia. Glencliff Home for the Elderly, Glencliff, NH, 1 February 1979.

Hamlet, M. P. Frostbite and hypothermia. Basic Wilderness Survival Course, Springfield Technical Community College, Springfield, MA, 6 February 1979.

Hamlet, M. P. Frostbite and hypothermia. Safety and Rescue Seminar, Northfield Mt, MA, 7 February 1979.

Hamlet, M. P. History of cold weather warfare. Cold Weather Medicine Symposium, Denver, CO, 22 & 23 February 1979.

Horstman, D. The role of O_2 transport in exercise performance. Southwestern Medical Center, Dallas, TX, April 1979.

Horstman, D. The role of O_2 transport in exercise performance. Texas College of Osteopathic Medicine, Ft. Worth, TX, April 1979.

Horstman, D. The role of O_2 transport in exercise performance. The Pennsylvania State University, State College, PA, May 1979.

Pandolf, K. B. Human performance of muscular work in hot environments. Concordia University, Montreal, Canada, 30 April 1979.

Vogel, J. A. Physiological capacities of the female. Conference on Women and Sports, Boston University, 28 October 1978.

APPENDIX G

MISCELLANEOUS

Goldman, R. F. Book Review. A Resources for the Future Book, by Lester B. Lave and Eugene P. Seskin., 368 pp, Johns Hopkins University Press, 1977. American Scientist 66:743, 1978.

Goldman, R. F. Book Reviews (1) Methodological Approaches to Deriving Environmental and Occupational Health Standards, Edward J. Calabrese, ed. Environmental Science and Technology, 402 pp., Wiley-Interscience, 1978; (2) Energy Utilization and Environmental Health: Methods for Prediction and Evaluation of Impact on Health, Richard A. Wadden, ed. Environmental Science and Technology, 200 pp, Wiley-Interscience, 1978; (3) Measuring and Monitoring the Environment, John Lenihan and William W. Fletcher, eds. Environment and Man Series, Vol. 7 131 pp, Academic Press, 1978. American Scientist 67:615, 1979.

APPENDIX H

SEMINAR PROGRAM

DATE	LECTURER	SUBJECT
12 October 1978	Experimental Pathology Division Staff, USARIEM Natick, MA	Division Research Program
13 October 1978	Scott V. Campbell University of Wisconsin LaCrosse, WI	Wealth Wellness & Lifestyle Tour on Health
17 October 1978	Heat Research Division Staff, USARIEM Natick, MA	Division Research Program
16 November 1978	Health & Performance Division Staff, USARIEM Natick, MA	Division Research Program
29 November 1978	Lars Larson, M.D. Karolinska Institut Stockholm, Sweden	Morphological & Functional Characteristics of Aging Skeletal Muscle in Man
8 December 1978	Barbara Avellini, Ph.D. Hypertension & Kidney Disease Laboratory Center, Inc. New York, NY	A Comparison of Sweating Responses in Men & Women Before & After Acclimation to Humid Heat
14 December 1978	Dale R. Bergren, Ph.D. Cardiovascular Research Institute University of California San Francisco, CA	Effects of Antigen and Ozone on Rapidly Adapting Pulmonary Receptors
18 January 1979	Military Ergonomics Division Staff, USARIEM Natick, MA	Division Research Program
6 February 1979	Carl Mandleco, Ph.D. University of Utah Salt Lake City, UT	Application of Ionotophoresis for the Non-Invasive Administration of Lidocaine in the Ionized Form

DATE	LECTURER	SUBJECT
12 February 1979	Carl A. Ohata, Ph.D. Department of Physiology & Biophysics University of Oklahoma Health Sciences Center Oklahoma City, OK	Temperature Regulation in Fur Seals
13 February 1979	Akira Adachi, Ph.D. Biomedical Research Division National Aeronautics and Space Administration Ames Research Center Moffet Field, CA	A Thermal Sensitive Hepatic Afferent and It's Role in Hypothermia Produced by Acute Hyper-G Exposure
1 March 1979	Altitude Research Division Staff, USARIEM Natick, MA	Division Research Program
15 March 1979	Exercise Physiology Division Staff, USARIEM Natick, MA	Division Research Program
27 March 1979	Obed Bar-Or, M.D. Director of Research Wingate Institute for Physical Education & Sports Wingate Post, Israel	A New Anaerobic Capacity Test - An Overview
23 April 1979	Jesse Summers, Ph.D. Institute for Cancer Research Philadelphia, PA	Viral Hepatitis & Its Possible Relationship to Cancer
3 May 1979	CPT Jared Jobe, Ph.D. Headquarters Combat Effectiveness Command Ft. Ord, CA	Human Factors Combat Effectiveness Development Command Field Experimentation
14 May 1979	James H. McCroskery, Ph.D. State University of New York Department of Psychology Oswego, NY	Biofeedback & Control of Heart rate
13 June 1979	Francis J. Haddy, Ph.D. Professor & Chairman Physiology Department Uniformed Services University of Health Sciences Bethesda, MD	The Sodium-Potassium Pump in Experimental Hypertension

DATE	LECTURER	SUBJECT
17 July 1979	Hon. Louis P. Bertonazzi Massachuestts Senate State House Boston, MA	Health Care Legislation
31 July 1979	R. Donald Hagan, Ph.D. Institute for Aerobics Research Dallas, TX	Plasma Volume Changes Associated with Posture and Exercise

APPENDIX I

CONFERENCE FOR DIVISION SURGEONS
4-8 December 1978

PRESENTATIONS

Exercise Physiology Division

Exercise Physiology Division Mission, tasking from DCSJPER and collaboration with TRADOC to revise PT program.

Fitness Levels: male vs. female, age, basic trainees, 2d Division, 1st Cavalry Division, other Armies.

PT Revision Project (MOS) Standards: MOS clustering, task analyses and measurement, standards formulation and AFEES profiling.

Age and cardiovascular health/safety considerations

Panel: Special considerations regarding women

Health and Performance Division

Psychological/physiological Reactions to Environmental Extremes and to Combat

Interactions with Operational Stresses

Impacts on Human Military Performance

Heat Research Division

Heat Research Division Program

Historical Perspective; Current Army Practice

Prevention of Heat Injury

Analysis of USA and Israeli Heat Doctrine

Acclimatization; Fluids; Prevention; Diagnosis; and Treatment of Heat Illness

Operational Problems

Experimental Pathology Division

Cold Injuries
Trenchfoot, Immersion Foot
Frostbite
Hypothermia
Notes for Commanders for Cold Weather
Operational Planning Problems

Altitude Research Division

Military Interest in High Altitude
Acclimatization
Altitude Environment
Altitude-Related Medical Problems
Medical Problems of Military Operations at High Altitude

Military Ergonomics Division

Terrestrial Environments
Tolerance Limits for Heat and Cold
Metabolic Heat Production during Military Operations
Military Standards for Comfort and Intolerance
Thermal Comfort - an operational definition derived from physiological principles
Cold and Heat Stress
Guide to Prediction Equations

PROBLEM I. Deployment of Contingency Ready Forces to a Hot Weather Area of Operations

PROBLEM II. Deployment of Contingency Ready Forces to a Cold Weather Area of Operations with Some Elevations Above 11,000 Feet

FUNCTION OF THE WORKING GROUPS

MEDICAL BRIEFING

APPENDIX J

CURRENT CONCEPTS IN ENVIRONMENTAL MEDICINE COURSE
21-25 May 1979

PRESENTATIONS

Environmental Research	Colonel Harry G. Dangerfield, M.D.
Environmental Assessment - The 8 Key Factors	Ralph F. Goldman, Ph.D.
Environmental Indices	Ralph F. Goldman, Ph.D.
Human Heat Balance Equation, Comfort and Temperature Regulation	Ralph F. Goldman, Ph.D.
Work	John F. Patton III, Ph.D. and Staff of Exercise Physiology Division
Heat	Milton Mager, Ph.D. and Staff of Heat Research Division
Prediction Modelling	Leander A. Stroschein
Water Immersion Prediction	Louis H. Strong, Ph.D.
Adjustments to High Altitude	Richard L. Burse, Ph.D.
Clinical Aspects of Altitude Exposure	John T. Maher, Ph.D.
Stress in Combat	LTC James W. Stokes, M.C.

Myths about Performance Under Stress	Louis E. Banderet, Ph.D.
Performance Degradation in Extreme Environments	John L. Kobrick, Ph.D.
Individual Differences in Susceptibility	Bernard J. Fine, Ph.D.
The Use and Protection of Human Subjects, an Essential Resource	Milton Landowne, M.D.
The Impact of Environment on Performance	Ralph F. Goldman, Ph.D. Murray P. Hamlet, D.V.M. Milton Mager, Ph.D. John F. Patton III, Ph.D. LTC James W. Stokes, M.C.

DEMONSTRATIONS

Display of Environmental Instrumentation	John R. Breckenridge Leander A. Stroschein Basavapathruni Onkaram
Testing: Eccentric Exercise Muscle Strength Aerobic/Anaerobic Exercise	John F. Patton III, Ph.D. and Staff of Exercise Physiology Division
Test Apparatus	Clement A. Levell Thomas L. Endrusick John R. Breckenridge

TOURS

Climatic Facility	Fred R. Winsmann
Tour of Pool	James Bogart

Decompression Chamber	James A. Devine
Animal Facilities	Murray P. Hamlet, D.V.M. and Staff of Experimental Pathology Division

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